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DEVELOPMENT, APPLICATION AND ASSESSMENT OF A TAXONOMY FOR CHARACTERIZING INTERNATIONAL ENVIRONMENTAL PROBLEMS

A Policy Analysis Exercise by:

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Jennifer A. Marrs

April 12,1990
John F. Kennedy School of Government

prepared for:

Professor Gordon Goodman
Director of the Stockholm Environmental Institute

presented to:

Dr. William Clark
Professor John Montgomery

Title: Development, Application and Assessment of A Taxonomy for Characterizing International Environmental Problems

Author(s): Marc D. Koehler
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Abstract:

As national leaders become increasingly aware of the environmental risks that modern technology adds to existing natural environmental problems, they have begun to search for ways to prioritize the risks they face. Several experts in risk assessment, including Professor Gordon Goodman of the Stockholm Environmental Institute, researchers at Clark University's Center for Environment, Technology, & Development (CENTED), and the United States Environmental Protection Agency, have already developed some hazard characterization taxonomies that attempt to fill this need. The Kennedy School of Government (KSG) taxonomy is the next iteration of taxonomies designed to characterize environmental problems. The purpose of this Policy Analysis Exercise (PAE) is to <u>test</u> and <u>evaluate</u> the KSG taxonomy. In order to accomplish these goals, the United States and India are presented as case studies. The final section of this PAE provides recommendations to policy makers who use the KSG taxonomy.

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Executive Summary

As national leaders become increasingly aware of the environmental risks that modern technology adds to existing natural environmental problems, they have begun to search for ways to prioritize the risks they face. Several experts in risk assessment including, Professor Gordon Goodman of the Stockholm Environmental Institute, researchers at Clark University's Center for Environment, Technology & Development (CENTED), and the United States Environmental Protection Agency (EPA), have already developed some hazard characterization taxonomies that attempt to fill this need. The KSG taxonomy is the next iteration of taxonomies designed to characterize environmental problems. The KSG taxonomy builds upon earlier models provided by Goodman, CENTED and EPA, and attempts to characterize a wider range of environmental problems for any nation in the world. (Earlier taxonomies were more restricted in the types of problems examined and (in the case of CENTED and EPA) were designed for use with a single country--the United States.)

The purpose of this Policy Analysis Exercise (PAE) is to test and evaluate the KSG taxonomy. In order to accomplish these goals, the United States and India are presented as case studies. These countries were chosen for testing the KSG model because they occupy opposite ends of the spectrums five criteria--climate, GNP per capita, population density, predominant economy, and culture. The results of the case studies reveal that the KSG taxonomy can be used to accurately characterize all of the 27

environmental problems attempted. Natural resource problems and natural environmental hazards are the most problematic for the KSG taxonomy but the taxonomy still adequately captures the characteristics most people are concerned with--human health, ecological effects, and welfare--for these problems.

Because of the problems revealed during the testing of the KSG model, we have recommended some modifications:

a. Omit the descriptors "intentionality", "transgenerational","recurrence", and "magnitude of future consequences".

b. Provide new definitions of standards for "delay", "spatial extent", "concentration", and "natural ecosystem impacts"

c. Rewrite the problem chains for Animal Habitat (9) and Stock of Wildlife (23) into a single problem chain called Species Diversity.

The final section of this PAE provides recommendations to policy makers who use the KSG taxonomy. We suggest the following to the policy maker:

a. Attempt different "weighting" schemes in order to help players in the political debate recognize the value judgments they make.

b. Expect public opinion polls to differ from the KSG results and use various mechanisms for including laypersons in the resolution of the policy debate.

c. Use uncertainty in a positive manner by allowing it to point out areas that require more scientific research and to induce others to help create a consensus building process.

d. Pay attention to the KSG descriptors that indicate whether a problem is local, regional or global and the descriptors that indicate whether future generations are affected.

Part I: The Need for a New Tool

I.A. Introduction

As societies face dwindling budgets and growing social problems, the need to prioritize environmental risks has become urgent. In the past, even a nation as large as the United States did not have an objective schema for deciding how to allocate efficiently the resources set aside to correct environmental problems. In 1987, U.S. Environmental Protection Agency administrator Lee Thomas wrote, "In a world of limited resources, it may be wise to give priority attention to those pollutants and problems that pose the greatest risk to our society."[1] Thomas could find no one in the largest U.S. government agency responsible for environmental policies who could tell him a basic list of the "worst" environmental problems facing the United States. The United States is not the only nation in the world that wrestles with this problem. Almost all of the nations around the globe are in desperate need of a way to decide which environmental problems pose the greatest risk to their societies.

In addition to providing a ranking mechanism within a nation, an objective schema can facilitate discussions between nations. During the last decade, a large number of countries have discovered that activities inside their border can contribute to environmental effects inside their neighbor's

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[1] United States Environmental Protection Agency. Unfinished Business: A Comparative Assessment of Environmental Problems, pg. ii.

borders and vice versa. Also, the whole globe faces environmental risks due to the activities of a few nations. In order to coordinate action on these types of problems, each country should be aware of the important, purely domestic environmental problems on which other nations need to take action before they can turn their attention to global ones.

The purpose of this Policy Analysis Exercise (PAE) is to test and evaluate a risk characterization taxonomy designed to help nations prioritize the attention they devote to environmental problems. The taxonomy to be examined in this PAE, called the "KSG taxonomy," is an attempt to build upon work done by Professor Gordon Goodman of the Stockholm Environmental Institute, researchers at Clark University at the Center for Environment, Technology & Development (CENTED) in their study entitled Perilous Progress, and by the United States Environmental Protection Agency whose study Unfinished Business was completed in 1987.

Part I of this PAE is a discussion of the tools upon which the KSG taxonomy was built and an in-depth look at the KSG taxonomy. Part II of this paper provides the results of an application of the KSG taxonomy to two countries--the United States and India. An evaluation of the KSG taxonomy is presented along with suggestions for improvement in Part III of the PAE, and in Part IV, guidance for policy makers who use this taxonomy is provided. Part V finishes with our conclusions and recommendations.

I.B. Review of Existing Tools

I.B.1. Gordon T. Goodman, "Some Criteria for the Priority Ranking and Selection of Urgent Environmental Issues"

In a 1980 discussion paper, Professor Gordon Goodman of the Stockholm Environmental Institute developed "a set of six criteria by which the severity and urgency of 29 widely disparate environmental issues...may be compared and ranked more objectively."[2] Although there have been many different rankings of environmental problems, Goodman suggests that variability in the evaluative process makes it impossible to obtain "a truly comparative assessment of the relative importance of all the widely different environmental issues."[3] Specifically, experts attempting to prioritize environmental problems tend to deal separately with problems affecting the atmosphere, oceans, freshwater, land or biological systems. In addition, the experts are themselves drawn from different backgrounds such as law, economics, biology, chemistry or toxicology. These two sources of variability, Goodman feels, make a "common point of view" impossible[4]

Goodman's schema is an attempt to remedy this problem. He

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[2] Goodman, G. "Some Criteria for the Priority Ranking and Selection of Urgent Environmental Issues", pg. 1.

[3] Ibid. pg. 3.

[4] Ibid. pg. 3.

develops criteria that address four types of human concerns. First, the **ultimate harm potential** of an environmental problem--the level of harm that will result if the problem develops unchecked--is assessed through five descriptors: severity and ubiquity of harm, persistence of effect after cessation of impact episode, and the frequency and duration of episodes. Second, the **latency potential** is characterized by two descriptors: visibility and time of onset. Third, the **current harm burden** is examined. Finally, the **harm burden growth**--the doubling time for the growth of the currently expressed burden--is assessed.

When a problem is assessed along these dimensions, a numeric profile (or "signature") is generated. Subsequently, any rankings of problems, expressed as numeric signatures, will be more transparent and clear:

> Everybody knows what assumptions have been made and where, so that differences in opinion about an issue can be traced back through the decision process to their precise origin. This takes the 'mystery' out of the ranking process.[5]

Goodman's schema is designed for a variety of environmental problems, ranging from natural resource depletion to risks associated with industrial development and urbanization. Although he has designed his criteria to assess problems at a global level, he has also indicated that comparisons at the level of national resource allocation and planning will be important.

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[5] Ibid. pg. 16.

I.B.2. Center for Environment, Technology & Development (CENTED), Perilous Progress: Managing the Hazards of Technology

Researchers based at Clark University's CENTED completed an extensive study on technological hazards in 1985. Part of their work involved the development of a causal taxonomy for assessing and ranking hazards. Hazards are described as:

> a sequence of causally connected events that lead from **human needs and wants**, to **choice of technology**, to **initiating events**, to **possible release of materials and energy**, to **human exposure**, and eventually to **harmful consequences.**[6]

Ninety-three causal chains of specific, narrowly defined technological problems (such as "toxic effects of 2,4,5-T herbicide" and "electric fields of high voltage wires") are defined and characterized in the study. For each problem, twelve descriptors measure the hazards at different sequences of the causal chain: the degree to which the technology is intended to harm is assessed in **intentionality**; the release of materials is assessed under **spatial extent, persistence**, **recurrence**, and **concentration** above natural background; exposure is measured by **population at risk** and **delay**; and consequences are assessed in **transgenerational** effects and **human** and **non-human mortality.** These descriptors are intended to be universally applicable, comprehensible to ordinary people, and capable of being expressed

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[6] Kates, R. et al (editors). Perilous Progress: Managing the Hazards of Technology, pg. 68.

by common units.

The motivation underlying CENTED's study came from what researchers termed the need for "a rational approach to triage":

> As a society we cannot make extraordinary efforts on each of the 100,000 chemicals or 20,000 consumer products in commerce. If our causal structure and descriptors reflect key aspects of hazards--threats to humans and what they value--then our taxonomy provides a way of identifying those hazards worthy of special attention.[7]

If hazards can be compared in an orderly and systematic way, the authors of Perilous Progress argue, then "the quality and effectiveness of hazard management" will be improved.[8]

I.B.3. Environmental Protection Agency, Unfinished Business: A Comparative Assessment of Environmental Problems

In 1987, citing limited resources and shrinking budgets, U.S. Environmental Protection Agency administrator Lee Thomas directed the EPA's Office of Policy Analysis to undertake an extensive study of the risks posed by 31 major environmental problems; for the most part, these problems were the ones for which EPA had statutory responsibility and existing programs. The resulting report, Unfinished Business, was an assessment and ranking of these problems along four dimensions: **cancer risks**, **non-cancer health risks**, **welfare** and **ecological risks**. No

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[7] Ibid. pg. 85.

[8] Ibid. pg. 85.

absolute ranking scheme was used to determine the "worst" problems since no one type of risk was seen to be more important than another; rather, problems were ranked within each type of risk category, and problems that were determined to be a high risk on any three of the four dimensions were placed in an overall high risk category.

Richard Morgenstern, the Director of the Office of Policy Analysis, noted two interesting results of the study. First, EPA researchers found that they were frequently hampered by substantial gaps in available data, leading Morgenstern to write, "In retrospect the project involved more judgement and less objective analysis than was expected."[9] Deficiencies in existing data meant that in many cases problems had to be assessed largely on the basis of "systematically generated informed judgement." Second, because no problems rank relatively high on all four types of risks, Morgenstern noted that "Whether an environmental problem appears large or not depends critically on the type of adverse effect with which one is concerned."[10]

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[9] Morgenstern, R & Sessions,S. "EPA's Unfinished Business", Environment, pg. 35.

[10] Ibid. pg. 36.

I.C. KSG Taxonomy

The KSG taxonomy was created by a research group[11] at the John F. Kennedy School of Government and is the next iteration in the process that was begun by Professor Goodman, researchers at CENTED, and the United States Environmental Protection Agency (EPA). This taxonomy sets out to characterize international environmental problems. It is meant to be used by national level policy makers (such as the Minister of the Environment in India or head of the EPA) as a tool for shaping the policy agenda by comparing the impact of different environmental problems on a single nation. The taxonomy is not meant to be a field-level tool for managing specific environmental problems. (So, even though some kinds of problems may be dealt with easily while other problems have no solution, the taxonomy characterizes both kinds.) The primary purpose of the KSG taxonomy lies with shaping the policy agenda, not the response. This model is intended to fulfill the need for a more objective tool to characterize and prioritize environmental problems in all countries around the globe.

In addition, the creators of the KSG taxonomy hope the model can be used to enhance international negotiations by comparing environmental problems across nations. For example, some developing countries in South America are under pressure from

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[11] This group was composed of Vicki Norberg-Bohm, William C. Clark, Marc Koehler, and Jennifer Marrs.

Western nations to apply resources to change activities that the Western nations feel are contributing to an environmental problem such as "global climate change" or "loss of biodiversity." The authors of the KSG taxonomy hope that the taxonomy's output will facilitate international discourse by showing the relative importance of the twenty-eight environmental problems in both the Western and South American nations. Western leaders may then see that the developing nations have environmental problems other than global climate change that are more immediate in nature--problems to which resources should be devoted first.

As stated above, the KSG taxonomy is an adaptation of earlier models discussed in the previous section of this paper. This taxonomy closely parallels Professor Goodman's taxonomy when it comes to the **types** of environmental problems the tool attempts to characterize. The KSG tool aims to characterize seven general types of environmental problems--a wide variety of hazards that are described in Table 1.

TABLE 1: ENVIRONMENTAL HAZARDS

WATER

1. Freshwater quality - biological contaminants
2. Freshwater quality - metals and toxins
3. Freshwater quality - nutrients and dissolved oxygen (eutrophication)
4. Freshwater quality - sedimentation
5. Ocean water quality

LAND

6. Soil salinity, alkalinity, waterlogging
7. Soil productivity, desertification (soil erosion, land degradation, soil compaction)
8. Quantity of arable land (loss of arable land to urbanization)

BIOTA

9. Quantity and quality of animal habitat
10. Pure food supplies (non-toxicity of food)
11. Rate of gene mutation (cryptic spread of mutant genes)

ATMOSPHERE

12. Ultraviolet energy absorption (stratospheric ozone depletion)
13. Thermal radiation budget alteration (climate change)
14. Acidification (acid rain)
15. Photochemical oxidant formation (smog, elevated tropospheric ozone)
16. Concentration of toxins (Hazardous and toxic air pollutants)

THE HUMAN ENVIRONMENT

17. Indoor air quality - radon
18. Indoor air quality - non-radioactive pollutants
19. Exposure to chemicals (including biological pathogens) in the workplace
20. Exposure to radiation (other than radon)
21. Accidental chemical releases

RENEWABLE RESOURCES

22. Stock of fisheries
23. Stock of wildlife
24. Forestry reserves
25. Groundwater resources

NATURAL ENVIRONMENTAL HAZARDS

26. Floods
27. Droughts
28. Pest epidemics

The causal chain approach to hazard characterization that the KSG taxonomy utilizes was taken from the ideas presented in CENTED's study Perilous Progress. Following CENTED's work, each of the environmental hazards named in Table 1 is defined in the KSG taxonomy as a "causal chain". The chain begins with **human activities** that initially cause a change in the environment. The human activities lead to **changes in material fluxes**. The fluxes alter something in the environment that humans value--**valued environmental components (VECs)**. Changes in VECs affect humans, wildlife, and plantlife through the **exposure** link in the causal chain. Finally, the environmental problem chain finishes with **consequences for humans and that which we value**. At each link in the chain, several descriptors attempt to measure (on a predetermined numerical scale) relevant characteristics of the environmental problem (Please See Table 2 on the following page and Appendix A for a text description of each of the 28 environmental problem chains).

The works by Goodman, CENTED, and EPA all provide a basis for the descriptors chosen for the KSG taxonomy (Please See Appendix A for a full description of the KSG descriptors and the accompanying scales). However, since the KSG model is intended for use in all countries of the world, several modifications to the existing descriptors were required. The descriptors **population at risk**, **land area or resource at risk**, **human mortality**, **human morbidity**, and **welfare effects** had to be modified for use in all countries. The scales for these descriptors became "% of land area", "% of population at risk", and "% of GNP". Moreover, the international scope of the KSG taxonomy also prompted the addition of a new descriptor. The descriptor "transnational" was added in order to characterize the extent to which the activities of nations contribute to the problems of their neighbors.

TABLE 3: CAUSAL CHAIN

HUMAN ACTIVITIES	CHANGES IN MATERIAL FLUXES	CHANGES IN VECs	EXPOSURE	CONSEQUENCES TO HUMANS AND THAT WHICH WE VALUE
Intentionality	Spatial extent		Population at Risk	Human Mortality
	Concentration		*Land area or* Resource at Risk	*Human Morbidity*
	Persistence		Delay	Ecosystem
	Rate of Change in Material Flux			Welfare
				Transgenerational
				Transnational
				Commitment to Future Health Consequences
				Commitment to Future Ecosystem Consequences
				Magnitude of Future Con

Part II: The "Experiment"

II.A. Strategy for Testing and Evaluation

In order to carry out the PAE charge of testing and evaluating the KSG taxonomy, the taxonomy was applied to two countries--India and the United States. This "experiment" was an opportunity to evaluate the strengths and weaknesses of the taxonomy. An interpretation of the India and United States results is presented in Part II of this paper.

Where possible, information from international organizations such as the United Nations Environmental Program (UNEP) and the World Health Organization (WHO) was used in an attempt to obtain relatively unbiased data from cross-country comparisons. Sources from non-governmental environmental groups such as the World Resources Institute (WRI) were also used frequently. In many cases, little or no data could be located for problems affecting India so informed judgments were made by using modified data from other countries. Overall, we have a high level of confidence in our characterizations of environmental problems in India and the U.S.

II.B. Criteria for Choosing U.S. and India

Our decision to apply the taxonomy to India and the United States was based on five criteria that include:

(1) Climate.
(2) Population density.
(3) GNP per capita.
(4) Predominant economy.
(5) Culture.

We were looking for diversity in these criteria, and for each one, India and the United States occupy opposite ends of the spectrum. Therefore, these countries provide an opportunity for the KSG taxonomy to be tested and evaluated under different domestic conditions. Table 3 illustrates the major differences between India and the United States:

TABLE 3: Criteria for Selection

	INDIA	UNITED STATES
1. **CLIMATE**[12]	dry tropical semi-arid mountainous	semi-continental prairie-stepped humid temperate semi-arid desert mediterranean mountainous
2. **POPULATION DENSITY**	250 per km^2	25 per km^2
3. **GNP PER CAPITA**[13]	$290	$19,800
4. **PREDOMINANT ECONOMY**[14]	agriculture nomadic herding some manufacturing some fishing	manufacturing agriculture forestry hunting/fishing
5. **CULTURE**	Asian	Western

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[12] The New York Times Atlas of the World, pg. 20.

[13] Central Intelligence Agency, The World Factbook 1989, pg. 17.

[14] Rand McNally Goode's World Atlas, pg. 28-29.

II.C.1. Results of the India Case Study

Twenty-seven environmental problems were assessed with the KSG taxonomy in the India case study.[15] The numeric profiles for each problem are given on the following page, and the data used to obtain each descriptor score is located in Appendix B. We did not generate an overall ranking of the problems on the basis of all 18 descriptors scores. Rather, three rankings are offered on the basis of welfare losses, ecosystem impacts, and human mortality. (In the last ranking, problems are ranked first by mortality, and ties are then broken by morbidity.) In each case, problems are separated into HIGH, MEDIUM and LOW risk categories. Please note that specific problem chains are identified by number in parentheses.

Mortality losses associated with the different environmental problems in India are categorized as follows:

HIGH	MEDIUM	LOW
Scores 7-5	Score 4	Scores 3-1
0.001-1% pop.	0.0001-0.001% pop.	<0.0001% pop.
7600-7.6 million	760-7600	<760

The six problems scoring HIGH mix First World risks associated with development and industrialization together with Third World risks associated with rural poverty. In the former group are Water Toxics (sic) (2) and Pure Food (10), both of which are driven by extensive use of pesticides and poor disposal of toxic

[15] Due to lack of data, cryptic mutant gene spread (11) was not scored for either the United States or India.

substances. Freshwater Biological Contaminants (1), which encompasses a plethora of water-born diseases such as cholera and childhood diarrhea, appears in the latter group along with Pest Epidemics (28), which encompasses insect-born diseases like malaria and filariasis. Additionally, both Indoor Air Radon (17) and Indoor Air Non-Radon (18) have high mortality rates.

Two problems in the MEDIUM category are related to hunger; both Desertification (7) and Droughts (27) are included because of problems of malnutrition. The LOW category contains a mixture of problems associated with natural resources. Exposure to Radiation (20) also receives a low rank due to the small size of India's nuclear power industry. Plans to expand nuclear power capabilities will probably shift this problem into a higher category.

Welfare losses for environmental problems are also broken into three categories:

HIGH	MEDIUM	LOW
Scores 8, 7	Score 6	Scores 5-1
0.1-10% GNP	0.01-0.1% GNP	<0.01% GNP
$0.21-$21 billion	$21-$210 million	<$21 million

For India, the six problems that score HIGH are primarily related to agricultural production. Desertification (7), Droughts (27), Soil Salinity (6) and Ozone (12) are all associated with high welfare losses through their contributions to loss of agricultural output. Forestry (24) appears because of the increases in fuel wood prices caused by poorly managed forests and increasing scarcity of supplies. At the other end of the welfare spectrum are many of the problems associated with highly industrialized countries. Among the 17 problems scoring LOW are Air toxics (16), Exposure to Radiation (20) and Chemicals (19), Acidification (14), and Photochemical Smog (15).

Two factors contribute to low level welfare losses for the problems in the LOW category. First, India is a developing nation with a large number of rural villages; while development is underway in many urban areas, this is not true of much of the countryside. Accordingly, losses associated with agriculture are relatively more important. Second, many of the damages associated with industrial development may be overlooked or de-emphasized in India. For example, the costs of water supply degradation are included under welfare losses, but standards for safe levels of pollutants are much looser in India than in the USA. Therefore, what may be counted as a welfare loss in the USA may not be counted in India.

Ecosystem losses are also categorized into three groups:

HIGH Score 9	MEDIUM Score 6	LOW Score 3
Species Extinction	Decline in Productivity	No Significant Effect

HIGH levels in India are primarily associated with the use and disposal of pesticides, as captured by Water Toxics (2) and Pure Food (10). Ecosystem losses to Animal Habitat (9) and Wildlife Stocks (23) are also considerable; animal habitat is under constant threat from India's growing population, and many Indian species are endangered or threatened. These results are not surprising; in the US case, the latter three problems also score HIGH.

Several problems score HIGH across rankings. Water Toxics (2) scores HIGH in all categories, and Pure Food (10) scores HIGH in Mortality and Ecosystem, and MEDIUM in Welfare. Five other problems score one HIGH and one MEDIUM: Freshwater Biological Contaminants (1), Desertification (7), Forestry (24), Droughts (27), and Pest Epidemics (28). These seven problems are associated with multiple hazards and can certainly be ranked among the worst in India today.[16] (Please see Table 4 on the following page.)

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[16] In an article in Scientific American, William Clark offers an explanation for this collection of problems. Describing low-income, high-density regions like India's Gangetic Plain, he writes:

> Here intensive agricultural development has been under way for centuries and has been joined in the past several decades by the rapid rise of industrial development in growing urban centers. Landscape degradation is the central problem as more and more people are employed on agricultural land that is already exploited to capacity. In addition, the rapid rise of heavy industry in such areas has led to pollution problems comparable to those that Europe faced several decades ago. (Scientific American, September 1989, p.52-3)

TABLE 4: INDIA CASE STUDY

MORTALITY

WELFARE		HIGH (7-5)	MEDIUM (4)	LOW (3-1)	ECOSYSTEM
HIGH (8-7)		Water-Toxics			HIGH (9)
			Desertification Droughts	Forestry	MEDIUM (6)
				Salinity, Ozone	LOW (3)
MEDIUM (6)		Pure Food			HIGH
		Water-Bio		Sediment, Oceans	MEDIUM
					LOW
LOW (5-1)		Pest Epidemics	Floods	Animal Hab, Wildlife	HIGH
				Eutroph, Radiation	
		Indoor Other Indoor Radon	Air Toxics, Chemical Acidification	Fisheries, Grndwater Photochemical Chemical Accidents	MEDIUM
				Arab Land, Clim Chang	LOW

II.C.2. Results of the USA Case Study

As with India, 27 environmental problems are assessed with the KSG taxonomy in the USA case study. The numeric profiles for each problem are given on the following page, and the data used to obtain each descriptor score is located in Appendix 2. Again, no overall ranking of the problems is attempted, and three rankings are offered on the basis of welfare losses, ecosystem impacts, and human mortality.

Mortality losses associated with the different problems are categorized as follows:

HIGH	MEDIUM	LOW
Scores 6,5	Scores 4,3	Scores 3-1
0.001-0.1% pop.	0.00001-0.001% pop.	<0.00001% pop.
2460-246,000	25-2460	<25

These categories differ by one order of magnitude from the categories used for India, reflecting the much lower mortality and morbidity rates in the USA.

In general, the high risk problems are all associated with the technological hazards found in an industrial society. As with India, Pure Food (10) and Water Toxics (2) score HIGH because of extensive pesticide use and poor hazardous waste management. Additionally, increased mortality rates due to fossil fuel combustion are counted under Acidification (14). Indoor Air Radon (17) and Indoor Air Non-Radon (18) complete the top five list.

Several problems appear in the MEDIUM category, and except for Floods (26), all are related to industrial and technological hazards: Air Toxics (16), Exposure to Radiation (20), Accidental Chemical Releases (21) and Exposure to Chemicals in the Workplace (19). And at the low extreme, the natural resource depletion and land use problems found in the developing world are not associated with high mortality rates in the USA.

Welfare losses are broken into three categories:

HIGH	MEDIUM	LOW
Score 7	Score 6	Scores 5-1
0.1-1% GNP	0.01-0.1% GNP	<0.01% GNP
$4.2-$42 billion	$.42-$4.2 billion	<$420 million

In the USA, four problems scored HIGH. Acidification (14) appears because of materials damages and losses to crops and forests. Indoor Radon (17) imposes high welfare losses because of the costs of testing for radon, improving ventilation and losses in property values. Sedimentation (4) is associated with the costs of increased dredging of waterways and siltation of dams. Droughts (27) are included because of substantial losses in agricultural productivity caused by natural forces.

Problems scoring LOW are generally associated with the more manageable aspects of agriculture and with natural resource management. In many cases--including Forests (24), Soil Salinity (6), Arable Land (8) and Desertification (7)--problems are being relatively well managed.

Ecosystem problems in America are categorized in the same manner as in India:

HIGH Score 9	MEDIUM Score 6	LOW Score 3
Species Extinction	Decline in Productivity	No Significant Effect

Problems are ranked HIGH in the USA for the same reasons as in India: Pure Food (10) is included because of the effects of pesticides, while Animal Habitat (9) and Stock of Wildlife (23) are included because many species are threatened or endangered.

In the US case, no problem scores HIGH in all three categories, and only three did so in two of the three categories: Acidification (14) and Indoor Radon (17) both rank high on Welfare and Mortality, while Pure Food (10) does so on Mortality and Ecosystem. Three other problems score one HIGH and at least one MEDIUM: Water Toxics (2), Sedimentation (4), and Droughts (27). These six problems, then, can be considered among the worst facing the USA due to their high risks in more than one category. (Please see Table 5 on the following page.)

TABLE 5: U.S. CASE STUDY

MORTALITY

WELFARE	ECOSYSTEM	HIGH (6-5)	MEDIUM (4-3)	LOW (2-1)
HIGH (7)	HIGH (9)			Droughts
	MEDIUM (6)	Acidification		Sedimentation
	LOW (3)	Indoor Radon		
MEDIUM (6)	HIGH			Pest Epid, Fisheries Water-Bio Eutrophication Ocean Water Photochemical
	MEDIUM	Water Toxics	Air Toxics	
	LOW			Ozone, Groundwater
LOW (5-1)	HIGH	Pure Food		Animal Habitat Wildlife
	MEDIUM		Radiation, Floods Chemical Accidents	
	LOW	Indoor Other	Chemicals in Work	Salinity,Desertif Arab Land,Clim Chan Forestry

II.D. Public Opinion Polls Comparison

II.D.1. India

The United Nations Environment Program (UNEP) conducted a survey in sixteen countries entitled, "Public and Leadership Attitudes to the Environment in Four Continents." Louis Harris and Associates, Inc. completed the fieldwork from February 1988 to June 1989. The sample of population was asked, "Do you think...is a major problem, minor problem or not a problem in this country or in other countries such as this around the world?" This study cannot be directly compared to ours since the respondents were not asked to prioritize the eleven problems surveyed. Therefore, they could have said all eleven problems were major problems. However, this study can give us some indication of the Indian people's attitudes about their environment.

"Loss of Agricultural Land", "Drinking Water Pollution", "Deforestation", "Desertification", and "Chemicals Dumped by Industry" were the top concerns of the public in India. Our KSG taxonomy results were similar with respect to the water problems, desertification and forestry. Our study differed, however, with pesticide use (pure food and pest epidemics) scoring high in our study as an overall risk and high in mortality losses. Our study also differed with respect to droughts as an overall high risk hazard to the society.

II.D.2 United States

Results of a poll conducted by the Roper Organization in the United States in December, 1987 and January, 1988, indicate that the American public's perception of high risk hazards include, "Active hazardous waste sites", "Abandoned hazardous waste sites", "Worker exposure to toxic substances", "Industrial water pollution", and "Nuclear accident radiation"[17]. Our study's results were quite different from the public's perception of high risk hazards. "Acidification" was ranked high by our study and ranked 19th out of 28 by the public. "Indoor Radon" and "Pure Food" were high risk hazards from our study and ranked 27th and 9th (out of 28) respectively by the public. "Water toxics" in our study resembles the "Industrial water pollution" in the Roper poll--the public ranked it 4th and we ranked it high. Our remaining high risk hazards, "Sedimentation" and "Droughts" were not specifically ranked by the public.

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[17] Environment, July/August 1988, pg. 38.

Part III: Guidance for the Analyst

III.A. Descriptor Modifications

The descriptors used in the KSG taxonomy are similar to many the ones used in other existing tools. Most have been adapted to handle a broader range of environmental problems that occur across nations. In the following discussion, we evaluate the usefulness of these adaptations. Additionally, we have used LOTUS and SST software to examine the distributions and inter-relatedness of many of the descriptor scores. Throughout this section, the descriptor titles appear in bold print. Where called for, we have placed suggestions for analysts who may try to adapt the model further (and for interested users of the model)at the end of the relevant subsection. Please refer to Appendix A for more details about each of the descriptors, and to Appendices B and C for details about the scoring of individual problems.

Finally, we remind readers that three different people scored the environmental problems for the USA case study, and two scored them for India (Vicki Norberg-Bohm scored problems 1-5, 12-16 in the USA case; Jenny Marrs and Marc Koehler scored the remainder of the USA case and all of the India case). Consequently, some descriptors were handled differently by different scorers. This fact underlines the need for increased clarity in descriptor definitions.

Technology Descriptor:

1. Intentionality

This descriptor measure "the degree to which the relevant technology is intended to harm." It scores 3 ("not intended to harm") 68% of the time, and 6 ("intended to harm non-human organisms") in all other cases, in roughly the same proportion across both India and the USA.

Most of the information generated by this descriptor is picked up elsewhere: when **intentionality** is scored 3, the **ecosystem** descriptor always scores 3 or 6, indicating low to medium levels of damage and no experienced species extinction. When **intentionality** scores 6, the **ecosystem** descriptor score ranges in equal proportions across medium damage or experienced species extinction (scores 6 or 9) for 82% of the cases. The **commitment to future ecosystem consequences** descriptor is similarly distributed. Perhaps the most consistent fact underlying the scoring of **intentionality** is the association of <u>all</u> of the high scores with the use, disposal or release of pesticides.

Overall, this descriptor conveys little useful information apart from the connection to pesticides. (Note, for example, that if two tanker trucks ruptured on the same road--one loaded with pesticides, the other with harmful chemicals other than pesticides--different scores would be assigned.) Although a descriptor like **intentionality** can reveal important information in some applications (as it did in CENTED's study of technological hazards), it is unimportant for the international environmental problems considered here. It should be omitted from the taxonomy.

Material Flux Descriptors:

Many environmental problems are similar in their initial appearance; for example, a release of CFC's or radon gas into the environment will tend to persist for a given amount of time--no matter where that release occurs. In many cases, then, nearly all of the material flux descriptors can be expected to be comparable across India and the USA. The important exception to this generalization involves the **rate of change in material flux** descriptor.

2. Spatial Extent

Distribution of the scores for **spatial extent** is nearly identical for both India and the USA. Most scores are either "small region" (33%) or "subcontinental" (46%). Water pollution problems tend to have a "subcontinental" impact, as do most forms of air pollution (score 5). However, pollutants that persist for long periods have more time to spread; Ozone (12), Climate Change (13), and Exposure to Radiation (20) are all classified as having "global" impacts (score 9) because of their high **persistence** scores (all last over 100 years).

As a measurement of the linear distance over which a single "release" exerts a significant change in the material flux, this descriptor is more useful for problems associated with "releases" of pollutants into the atmosphere or water, and less useful for "releases" in land and renewable resource problems. In the former case, useful information is generated about the effects of a release on others living downwind or downstream; management of pollution problems will be handled differently when the release site is next door or hundreds of miles away.

Spatial extent makes less sense in the context of natural resource and land problems. What is the spatial extent of "single release" in terms of Stock of Wildlife (23), Desertification (7), or Pest Epidemics (28)? Should the analyst focus on the human activity or the natural causes of the problem? While a definition of "spatial extent" can be attempted for each problem, doing so in a consistent manner does not seem possible.

We recommend that **spatial extent** be scored in terms of the categorical scale provided in the model for problems in which linear dimensions do not make sense. For example, while the spatial extent of a drought <u>release</u> is unclear, the categorical scale of a <u>region</u> is not. Note that this specification does <u>not</u> change **spatial extent** into another measurement of **land area at risk**; it is sensible to speak of several small regions of drought that affect a large percentage of the land area in a country.

3. Concentration

The degree to which the **change in material flux** (rate of release for pollutants, rate of harvest for natural resource depletion, current level of releases for natural disasters) is above a given **base level** (natural background for pollutants, safe or sustainable levels for resource depletion, average level for natural disasters) is measured by a ratio R:

R = change in material flux/base level

The distribution of R was similar in the India and USA cases, and no problem received a score that differed by a value of more than 2 across the countries.

In the KSG taxonomy, **concentration** scores convey little new information. For 41% of the problems scored, the value of R ranged between 1 and 10 (score 3), indicating a level of concentration that ranges from slightly above the base level to a level ten times as high--but a difference of this magnitude can be crucial for natural resource depletion problems. In 33% of the cases, R's value was greater than 1 million (highest score 9), which generally indicates that the pollutant does not occur naturally--but information regarding the concentration above levels regarded as safe for humans would be more useful. Only three problems scored between 100 and 10,000 (scores 5 and 6) and no problems scored between 10,000 and 1 million (scores 7 and 8).

The specification of base levels is problematic in some cases. For example, establishing the base level for Quantity of Animal Habitat (9) or Stock of Wildlife (23) must involve a judgement about the **values of species preservation versus development**. Base levels are also unclear for other problems, such as Arable Land (8) and renewable resource problems (22-25).

Due to these results, re-scaling of descriptors and re-specification of base levels is recommended. Specifically, we suggest that safe levels of exposure, as determined by groups like the World Health Organization or the Environmental Protection Agency, be substituted for natural backgrounds whenever possible. Moreover, our results indicate that some of the higher score categories are too high; **concentrations** above R = 10,000 (scores above 7) are not observed. Re-scaling should allow for more detailed differentiation at lower levels, especially in the ranges where renewable resource depletion occurs (1 < R < 10).

4. Persistence

The time period over which a single release has measurable consequences to health, ecosystems and welfare is measured by **persistence.** Like most of the other material flux descriptors, **persistence** scores are similar for problems in India and the USA: 75% of problems have the same score, and only two problems differ in score by more than 2. In half of the problems, releases persist for over 100 years (score 9), and in a quarter of the remainder they persist for 10 to 100 years (score 8). These problems are primarily associated with natural resources, agricultural activity and the release of long lasting pollutants.

This descriptor generates useful information and can be scored consistently. No modifications are recommended.

5. Recurrence

The time period between significant releases is measured by **recurrence.** In 83% of the problems, recurrence is continual and the lowest score is given. Only environmental hazards--Floods (26), Droughts (27), Pest Epidemics (28)--and Accidental Chemical Releases (21) recur less frequently than every hour (score 4).

The **recurrence** descriptor does not seem to be correlated with any other descriptors, and it does not convey very useful information. (Moreover, one could argue that it is scaled backwards: higher scores are meant to indicate worse problems, but the rare and dramatic problems that are assigned high scores are precisely the ones receiving attention, whereas the ongoing, familiar problems that claim lives one by one are often ignored. Problems from the latter group are the most costly in terms of human health, welfare and ecosystem damage.) Because it offers little useful data, we recommend that this descriptor be omitted from the taxonomy.

6. Rate of Change

The rate at which the material flux is growing or diminishing is measured by **rate of change.** This is the only material flux descriptor that differs widely between problems in India and the USA; problems that are growing worse in one country are often improving in the other. In 46% of the problems, the material flux is growing at a slow rate (below 1.7%, score 6) and in 15%--it is stable (no change, score 5). Of this group, 7 of the 8 problems are found in the USA. Eleven problems in the USA are either stable or diminishing, while only two in India are.

Overall, this descriptor is one of the most useful. However, we recommend that its definition be clarified; users are reminded to focus on the notion of the doubling (or halving) time of the material flux. Additionally, it is interesting to note that descriptors similar to this one could be placed at several links in the problem chain. Goodman, for example, focussed on the rate of change in the current level of harm in a descriptor he calls "harm burden growth."

Exposure Descriptors:

7. Population at Risk

While nearly everyone may face some level of risk from a given environmental problem, **population at risk** was scored with health effects in mind. Americans were found to face the lowest level of risks to health over more problems (48%) than were their Indian counterparts (30%). Americans are primarily at risk from air pollution and the presence of non-natural pollutants and toxins in the environment. Indians are primarily at risk from hunger caused by droughts and desertification, and from water-and-pest born diseases such as malaria and filariasis.

As might be expected, **population at risk** scores are related to the **concentration** descriptor scores; when **concentration** is scored 9 (more than 1 million times above base level), **population at risk** has a score of 5 or higher (10% or more of the population) in two thirds of all cases; stable or decreasing levels of **concentration** (score 1 or 2) are always associated with a **population at risk** score below 5 (less than 10% at risk).

Of course, people are at risk in many ways from environmental problems: welfare losses and losses in the quality of life are two examples. We have focussed on risks to human health not because the others are unimportant, but because health losses are more readily quantifiable than the others. We recommend that users of the KSG taxonomy <u>define</u> <u>clearly</u> the level of risk they assume for this descriptor.

8. Land Area or Resource at Risk

This descriptor measures the percentage of the resource at risk of exposure to an environmental problem. No special patterns of distribution or correlation with other descriptors is noticed, in part because the scale of the relevant resource is narrowly defined for most problems. Establishing the denominator of this equation can be problematic, however. For example, is the resource at risk in Soil Salinity (6) all irrigated lands or all agricultural lands? Users of the taxonomy are reminded to <u>define in explicit terms</u> what the <u>relevant resource</u> is for each problem.

9. Delay

Scores for the **delay** descriptor, which measures the time period between the initial release and the occurrence of consequences, are clustered around three values: 24% are scored 1 (instantaneous consequences), 19% are scored 6 (1 month to 1 year), and 37% are scored 8 (10 to 100 years). The first category covers most of the renewable resource problems, the second covers problems related to agriculture and hunger, and the third covers problems associated with the harmful effects of industrial pollutants (such as increased cancer rates).

Like the material flux indicators already discussed, the **delay** between release and consequences should be similar for most environmental problems, whether they occur in India or the USA. And, although similar score distributions are found in most cases, several substantial differences appear too. The main reason for these divergences seems to be a lack of clarity about the relevant delay (for example, which **delay** should be scored for a release of pesticides--the immediate consequences, such as poisoning, or the cancer that may occur 10 years later?)

We recommend that **delay** be defined in terms of the <u>first significant consequence</u>. For example, in human health problems, a significant consequence is similar to the definition of **morbidity:** interference with normal activity.

<u>Consequence Descriptors:</u>

10. Mortality

Fourteen problems in the USA (52%) receive the lowest **mortality** score. All problems associated with renewable resource depletion and agriculture (including Droughts (27) and land related problems) are scored 1. The highest ranking problems are all related to high levels of industrialization: Water Toxics (2), Air Toxics (16), Exposure to Chemicals (19) and Radiation (20). Pure Food (10) receives the highest score (score 6) of all. In India, ten problems (37%) have the lowest rank; unlike the USA, however, medium levels of **mortality** are associated with losses to agricultural output and the subsequent malnutrition. The highest scores are found with a mixture of problems from the developed and developing worlds, including Freshwater Biological Contaminants (1), Pest Epidemics (28), Water Toxics (2) and Pure Food (10).

Overall, this descriptor is consistently applied and the information provided is very useful. Although no problem ever scores higher than 7 (0.1 to 1% of the population), re-scaling is not recommended; the **morbidity** descriptor uses the same scale and comparisons across the two are informative. No modifications to **mortality** are recommended.

11. Morbidity

Twenty problems are associated with the lowest **morbidity** score--12 in the USA and 8 in India. In most cases, the problems that score high here are the same that score high in **mortality**, and in all but 6 cases (11%) the **morbidity** score is within two points of the **mortality** score. Half of the problems that depart from this pattern are related to malnutrition in India; people go hungry for long periods but do not starve.

14. Transgenerational 3 6 9

NOTES:
Assume species resistance is essentially permanent.

15. Transnational 3 6 9

NOTES:
Pesticide application by neighbors will affect pests in USA.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
Current health effects are minimal; assume future will not be significantly worse.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:
Increased resistance will cause increasing problems.

18. Magnitude of Future Consequences. 3 6 9

NOTES:

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The main difficulty encountered involves the definition of **morbidity.** Although we used "permanent injury or injury that interferes with normal activity" as a guide, it is important to note that individuals in developing countries may be ill or malnourished for very long periods of time during which they must continue working; the definition of "normal activity" may differ in different nations. In general, however, this descriptor is useful and useable. No modifications to **morbidity** are recommended.

12. Ecosystem

The distribution of scores for **current ecosystem impacts** is similar in the USA and India. Only eight problems receive ranks that differ--and these differ by one step. In India, Forestry Reserves (24) and Desertification (7) rank relatively worse, while in the USA problems associated with air pollution do so.

An important difficulty in scoring this descriptor lies in defining "significant decline in productivity" (score 6) and "extinction of significant species" (score 9). Does a "significant" decline involve one species or five? Is the snail darter "significant?" We have focussed on actions which endanger threatened species or which cause localized extinctions for the former case, and on <u>any</u> amount of species extinction in the latter, but we recognize that these definitions are debatable. Nonetheless, the necessity for picking some definition is important here, and the ones we suggest are closely tied to the recognition of the values of species diversity.

13. Welfare

Welfare losses are widely distributed for both India and the USA. For India, the highest losses are related to agriculture. Soil Salinity (6), Droughts (27), Desertification (7) and Ozone (12) are all scored 6 or 7 (higher than 0.01% of GNP). America's highest losses come from diverse areas; Sedimentation (4), Acidification (14), Indoor Radon (17) and Droughts (27) all score 7 (0.1 to 1% of GNP). No significant correlation between **welfare** and other descriptors is noticed.

A potential problem with **welfare** involves the limits placed on the descriptor: losses are defined as losses to materials, crops, recreation, resources and water supply. Other losses, such as lost work days or health related costs are not included. However, this specification is problematic; for example, 73 million lost work days result from water born diseases in India annually. Clearly, costs of this magnitude place enormous burdens on Indian society.

Moreover, focussing only on the costs of a problem may cause the user to lose sight of any benefits that are brought about. The costs of pesticide use (captured in Pure Food (10), for example) are high, but the benefits in increased agricultural output are much higher. The welfare losses of conversion of Arable Land (8) are considerable, but the benefits in increased housing or industry may offset these losses several times over.

Clearly, users of the KSG taxonomy cannot be expected to perform extensive benefit-cost analyses for each environmental problem they score, but some consideration of the benefits associated with an activity that imposes environmental costs is recommended.

14. Transgenerational

The **transgenerational** descriptor is closely tied to **persistence.** In 87% of the cases where **transgenerational** scores 9 ("more than one future generation affected"), **persistence** scores 8 or above (longer than 10 years). In 88% of the cases where **transgenerational** scores 3 ("only current generation affected"), **persistence** scores are lower than 8 (less than 10 years).

This descriptor is ill defined and redundant. If the user is expected to focus on the commitment to future consequences from today's activities--the approach the KSG research team took in the case studies--then **persistence** offers a clearer measure of the potential for future hazards. Alternatively, if the user is expected to focus on current trends in the management of the hazard, then other descriptors offer clearer information (especially, **commitment to future human health consequences** or **commitment to future ecosystem consequences**). This descriptor offers little new information and should be omitted.

15. Transnational

Transnational scores are closely related to the scores of the **spatial extent** descriptor. For most problems, high scores for **spatial extent** are accompanied by high scores for **transnational.** Renewable resource problems and natural environmental hazards are exceptions to this generalization; problems like Floods (26) or Fishery Depletion (22) can be influenced by neighboring countries, even though they have low scores for **spatial extent.** As noted above, **spatial extent** is not clearly defined for these types of problems; changes in the definition of **spatial extent** should complete the link between it and **transnational** for most problems.

16. Commitment to Future Health Consequences

Commitment to future deaths (score 7 or 9) from contemporary activities and trends is predicted for 41% of the problems in India and 19% of the problems in America. For 52% of the American environmental problems, and for only 22% of the Indian problems, **commitment to future health consequences** receives the lowest score. The highest score (score 9), indicating "genotoxic lethality spreading through successive generations," is assigned to the same 6 problems (22%) in both nations; all these problems are associated with exposure to radiation and industrial chemicals.

Not surprisingly, this descriptor's link with current levels of **mortality** is very strong; in 90% of cases where **future health** rankings indicate expected mortality (scores 7 or 9), current **mortality** rates are greater than zero (score higher than

1). And in over 80% of the cases where people are dying now, mortality is predicted to continue.

While not clearly stated in the KSG taxonomy, this descriptor (and the two remaining descriptors) is intended to be applied under an assumption of "business as usual"; in other words, it is assumed that no change in current trends of management activities will occur. Therefore, a very strong indicator of whether people will be dying from a given problem in the future is whether they are dying from it now. While this assumption is not trouble free, no projection about the future will be. We recommend that the user base judgements about the future on existing trends as much as possible.

We also recommend deleting the word "commitment" since it can lead a scorer to think in terms of, "What happens if the causal activities stop today?' rather than in terms of trends.

17. Commitment to Future Ecosystem Consequences

The distribution of scores for this descriptor--which measures the impact of current activities on future ecosystems--is similar in the USA and India. Slightly more problems receive high scores (score 6 or 9) in the USA than in India (63% versus 52% of problems) due to higher levels of industrialization and pollution.

As with the previous descriptor, a good indication of **future ecosystem consequences** can be found in current **ecosystem** scores. In India, 93% of the problems received the same score on both descriptors, while in the USA 70% did so. Environmental protection in India does not seem to be a governmental priority; not many of the existing trends in environmental deterioration are being reversed.

We recommend deleting the word "commitment" from this descriptor name because, like descriptor #16, the scorer could be mislead and end up not scoring the descriptor using trend information.

18. Magnitude of Future Consequences

In approximately equal proportions across India and the USA, **magnitude of future consequences** is given the highest score ("future consequences greater than current ones") for 74% of the problems. Two lines of reasoning seem to lead to assignment of the highest score. First, if either the **persistence** of releases or the **rate of change** receives high scores (8 or 9), then **magnitude** receives the top score in 88% of the cases. Alternatively, if either **commitment to future health consequences** is scored high (scores 7 or 9), or if **commitment to future ecosystem consequences** scores high (score 9), then **magnitude** received the top score in 75% of the cases (for this group, the remaining cases are all associated with increasing welfare losses). In either case, little new information is generated. We recommend that this descriptor be omitted.

III.B. Problem Chain Modifications

The KSG taxonomy is based on the CENTED technique of characterizing environmental problems as causal chains. CENTED researchers were primarily concerned with technological hazards, and the chain they developed is well suited to environmental problems in which releases of materials into the environment cause problems. Thus, to the extent that the problems we examined were of this nature, little difficulty was encountered in describing them as causal chains; environmental hazards that occur primarily through the media of air, water and the human environment lend themselves well to this characterization.

For some problems, however, characterization as a causal chain is somewhat odd. For example, in many of the renewable resource and natural environmental problems, the "change in material flux" link and the "change in valued environmental component link" are nearly equivalent: "an increase in water in rivers and lakes" (material flux) is essentially the same as "increased flooding" (valued environmental component); "loss of forests, wetlands and other environments" (material flux) is essentially the same as a decrease in the "quantity of habitat" (valued environmental component). This problem does not cause difficulties for scoring and has few practical ramifications. The main point is a conceptual one: not all environmental problems lend themselves well to the five-link chain we are using.

For the most part, the causal chain specifications chosen for use in the KSG taxonomy "capture" important environmental problems well. One exception, however, lies with the attempts to capture the "biodiversity problem." The KSG taxonomy attempts to account for loss of species diversity primarily through two problem chains: Quantity of Animal Habitat (9) and Stock of Wildlife (23). There are several difficulties with this approach. First of all, loss of species diversity in plants is not clearly accounted for, even though plants provide the genetic raw materials for much research in medical and agricultural fields. Second, many non-commercial animal species will be "overlooked" under the current specification: hunting is the primary human activity of relevance for Stock of Wildlife (23). Third, the loss of animal habitat is not, in itself, a major problem; rather, it is the loss of species that people seem to care about most. Finally, and most importantly, the model implies in both problems that the user should focus on the quantity of wildlife itself rather than on the quantity of species, even though smaller quantities of a wide variety of species may be preferable to larger quantities of a few species.

We recommend, therefore, that these two problems be combined into a new one: Species Diversity. The **human activities** of both problems (primarily hunting and habitat destruction) are brought together, and they combine to give rise to a change in the **material flux** that will involve a decrease in the quantity of wildlife and plants, which in turn forces a change in the **valued**

environmental component of species diversity. The **consequences**, then, are experienced and potential losses to welfare and other things we value.

Alternatively, one might want to replace only Quantity of Animal Habitat (9) with the new problem chain, leaving Stock of Wildlife (23) in place, explicitly to handle the costs of diminished stocks in terms of the diminished tourism or foodstuffs, etc., that animal resources generate. For countries like Kenya, this problem may be one of the more important. But this problem would still be different from the biodiversity issue, and the latter one can be usefully captured in a Species Diversity problem chain.

Part IV: Guidance for Policy Makers

IV.A. Value vs Scientific Judgment

Whether or not an environmental problem seems relatively more important will depend upon the characteristic(s) of the environmental problem with which one is concerned.

The KSG taxonomy is a potentially valuable tool to use in the political process--just as EPA's Unfinished Business was. The KSG taxonomy only characterizes environmental problems by using 18 different descriptors. At the outset, none of the descriptors are initially chosen by the user of the KSG model to be more important than the other descriptors.

But, as we demonstrated in Part II by choosing to "weight" certain descriptors (human health, welfare effects, ecological effects, etc) differently, environmental problems can seem more or less important depending on what one cares about or values. In order to move from a single list of 18 numbers for an environmental problem to the next step of "clustering" the environmental problems, the user is required to make a value judgement about which descriptors should weigh more heavily than others.

A policy maker using the KSG taxonomy is advised to attempt several different weighting schemes to determine if any environmental problems rank relatively high on all of the schemes. Also, attempting different weighting schemes is likely to help a policy maker understand why different groups with a stake in the political debate often rank the importance of several environmental problems differently.

Through explicit decisions to weight key descriptors, the value judgments concerning what society cares about (human health consequences or welfare effects or ecological effects or future generations) can be kept separate from the more objective process of characterizing the hazards.

RECOMMENDATION:

-Attempt different "weighting" schemes in order to help players in the political debate recognize the value judgments they make.

IV.B. Public Opinion

The environmental problems from the KSG model output which rank relatively high or low on several weighting schemes will often differ from public opinion polls conducted in the nation.

The dilemma of discovering the correct balance between participation by scientific experts and laypersons of a nation in the environmental priority setting process is not a new one. However, modern technological hazards change the nature of this dilemma. Sheila Jasanoff, in her book Risk Management and Political Culture, writes,

> One feature that clearly distinguishes modern risk management from past policy disputes is **the increased demand by private citizens for a role in public decision- making.** Technological hazards not only threaten individual health and safety, but raise

> thorny distributive questions about apportioning the costs and benefits of development across societies and between present and future generations. Increasingly, citizens in the industrialized nations are reluctant to commit the resolution of such issues to the exclusive jurisdiction of experts and the state.[18]

How much should a policy maker worry that the output from the KSG model may differ from public opinion (as gauged by opinion polls conducted in the nation)?[19] At first glance, with the public becoming increasingly more vocal on hazard priority setting in most nations, a policy maker does have reason to worry that the results of the KSG taxonomy might be quickly drowned out by public opinion.

However, the public did not disregard the results of a study conducted by the United States Environmental Protection Agency (EPA), despite the fact that public opinion polls differed greatly but not completely from the results of EPA's study Unfinished Business. The Roper Organization in the United States conducted for example national surveys in 1987 that polled public attitudes about environmental problems. There were major differences between the environmental problems that were ranked important by the public and those that EPA ranked as the most important of the problems studied in Unfinished Business.

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[18] Jasanoff, Sheila. Risk Management and Political Culture, pg. 55.

[19] The "public" is not a homogenous group of people with the same opinions, but for this section the assumption of a somewhat homogeneous "public" will be used to distinguish this group from scientists and technical experts.

Why might this be the case? Richard Morgenstern (the project leader of Unfinished Business project for EPA) and Stuart Sessions write in Environment,

> Research has shown that people (the public) often overestimate the frequency and seriousness of dramatic, sensational, dreaded, well-publicized causes of death. In contrast, they often underestimate the risks from more familiar, accepted causes that claim lives one by one.[20]

Despite the major differences between public opinion and the EPA results, the EPA study was not quickly dismissed by citizen groups and the constituents. The participants in the EPA study were quite surprised by the positive reaction to the study. Morgenstern and Sessions write in Environment that the most surprising aspect of the positive reception was that there was a widespread acceptance of the two major underlying premises of the study, "...that objective risks should be a major factor in determining environmental priorities and that the expert judgment of agency personnel provides a useful source of such information."[21] Both Congress and the public responded positively to the unrecognized environmental problems that Unfinished Business flagged without reducing the amount of funds put toward the recognized but perhaps less riskier hazards.

Researchers at Clark University who authored the study Perilous Progress also encountered a difference between laypersons perceptions of hazards and the scientific community's

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[20] Morgenstern, R. & Sessions, S. Environment, pg. 36.

[21] Morgenstern, R. & Sessions, S. Environment, pg. 38.

perceptions of the same environmental hazards.

The CENTED team asked a group of thirty-four college-educated people in Eugene, Oregon to score 81 hazards using the taxonomy the CENTED team had created. The authors of the study write,

> Perhaps the most striking aspect of these results is that perceived risk shows no significant correlation with the factor mortality. Thus, the variable most frequently chosen by scientists to represent risk appears not to be a strong factor in the judgment of our subjects.[22]

Laypersons in the CENTED pilot study tended to overscore the hazards scored low by the scientists who used the taxonomy and to underscore the hazards scored high by the scientists. Deviations of a factor of a thousand between the estimates of technological risks were encountered in the two groups who used the CENTED taxonomy were encountered.[23]

CENTED's work was not in a spotlight like EPA's Unfinished Business study was and therefore not subject to the same type of scrutiny from Congress and the American public. Without the same type of scrutiny by the public, it is difficult to gauge the acceptance of CENTED's study. However, the authors of Perilous Progress provide valuable advice--policy makers should be aware of *why* risk perception varies across groups with the society.

Nations across the globe deal with differing perceptions of

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[22] Kates, R., Hohenemser, H. and Kasperson, J. (editors) Perilous Progress, pg. 80.

[23] Kates, R., Hohenemser, C. a. Kasperson, J. (editors). Perilous Progress, pg. 79.

laypersons and the science community in several ways. The American participative policy process for reaching decisions on environmental problems has been described by Sheila Jasanoff as, "...formal, open, adversarial, and confrontational while the European or Canadian approach is informal, confidential, consultative, and cooperative."[24] She goes on to write that individual citizens and citizen groups are much more influential in the United States because the individual citizens and the citizen groups are able influence policy through extensive litigation avenues.

Western nations (other than the United States) use the multiparte expert group to set priorities in the environmental policy arena and to attempt to strike a balance between lay participation and expert opinion. The multiparte expert group includes a host of interest group representatives (who are not research scientists) in addition to technical experts.[25] In the United States, advisory committees often contain only technical experts, although this trend has been changing. The multiparte expert group, in contrast, sets up a mechanism for negotiating both value differences and scientific differences. (However, some lay participants in these multiparte groups have questioned whether the credibility of laypersons in these groups is as

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[24] Jasanoff, Sheila. Risk Management and Political Culture, pg. 56.

[25] Jasanoff, Sheila. Risk Management and Political Culture, pg. 58.

powerful as it theoretically should be since the scientists seem to have more credibility on <u>both</u> value and scientific issues at times.)

During an international forum on Science for Public Policy held at the International Institute of Applied Systems Analysis (IIASA) in January of 1984, members of Forum Panel 1 proposed several different mechanisms for the participation of the public in the policy-making process. These mechanisms included:

(1) The "jury" model.
(2) Public hearings.
(3) Selected public representatives.
(4) Referenda.[26]

The forum members agreed that referenda were usually not a good mechanism for resolving issues but they did feel the "jury" model could be an effective way to resolve issues if the public members in the process work closely with the scientists. Most forum members felt the model that should be used to include the public in the decision-making process depended on the type of issue to be resolved.

Since the United States policy process is very accessible to laypersons through the litigation process, a policy maker using the KSG taxonomy in the United States (or any other similar taxonomy such as EPA's, CENTED's or Goodman's) whose results are likely to differ from public opinion polls may initially worry about the differences. However, the United States Environmental

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[26] Brooks, Harvey & Cooper, Chester. <u>Science for Public Policy</u>, pg. 233.

Protection Agency's study Unfinished Business was rather well-received despite major differences from public opinion polls. When a policy maker in the United States or any other nation faces this situation, he or she can turn to a multiparte expert group, the "jury" model, public representatives, referenda, and public hearings.

RECOMMENDATIONS:

- **Expect a difference in the results from the KSG taxonomy and public opinion polls.** (These differences have been documented in this study, as well as in a sizeable number of studies conducted over the last decade)

- **View the KSG taxonomy as another tool to help with priority setting since public opinion (also a tool for priority setting) cannot and should not be disregarded.** (However, keep in mind that the KSG taxonomy is striving to be a more objective priority-setting mechanism than the other tools that exist in the policy arena)

IV.C. Uncertain Inputs

Various inputs that a policy maker will "plug into" the KSG taxonomy are going to be highly uncertain--use this uncertainty in a positive manner.

As a user of the KSG taxonomy, a policy maker is going to have to be a consumer of hazard assessments done by other groups (as we were when using EPA's data from Unfinished Business to score some of the descriptors for the United States). There is nothing novel about a policy maker consuming the research results of other groups', but the KSG taxonomy has no mechanism for indicating how uncertain the input to the taxonomy was. For example, the score of the mortality descriptor for floods in the United States is much more certain than the score for the U.S. radon mortality descriptor. The KSG model is just one tool of many that is required to operate in an inevitably uncertain world. However, if a policy maker does not handle the uncertainty properly, then it is more likely that others will chose to overlook the valuable contributions the KSG taxonomy can make to the priority-setting process and focus exclusively on the scientific input which becomes the object of fierce disputes.

Ronald Brickman (who at the time of writing this advice was serving on the staff of the US Congress) discusses in Science for Public Policy two successful ways in which a policy maker can positively deal with uncertainty when attempting to resolve scientific issues.[27] Brickman's first suggestion is to let the uncertainty point you down the road of developing programs for new information generation. A fine example of encouraging uncertainty to have a positive effect on the policy-making

[27] Brickman, Ronald. Science for Public Policy, pg. 90.

process comes from a lesson learned by EPA while conducting the Unfinished Business study. Morgenstern and Sessions write in Environment,

> **Besides highlighting experts' views, Unfinished Business has also given EPA an agenda for improving data and methods for performing environmental risk assessments.** The participants found it impossible to perform this project in a quantitatively rigorous fashion. The best information the agency has is on the environmental causes of cancer, but even here the data is weak. There is a general lack of information on and attention to welfare and ecological effects. Members of both the ecological and welfare work groups felt that EPA has paid far too little attention to these sorts of concerns relative to the amount devoted to human health.[28]

Brickman's second suggestion is to develop institutions and procedures to further consensus when science is inadequate. He writes, "The more the decisions hinge on the outcomes of science, the more publicly exposed the inability of science to fashion an agreement. Science information then becomes the object of dispute. But scientific analysis cannot substitute for legitimate political authority."[29] Developing consensus in United States may be more difficult than in some other countries with so many players in the arena, although, the American system may separate fact from value a little better than other systems. Some people have suggested that a variation of "consensus building" may be "compromise building", which may work better in

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[28] Morgenstern, R. and Sessions, S. Unfinished Business, pg. 37.

[29] Brickman, R. Science for Public Policy, pg. 91.

the United States.

RECOMMENDATIONS:

-Use the uncertainty to point you down a road which needs further research

-Use the uncertainty as a reason to create consensus-building organizations

IV.D. Policy Agenda Process

Pay close attention to the KSG descriptors "transnational", "spatial extent", "land area", as well as the descriptors characterizing the future affects of an environmental problem. These are likely to be characteristics of an environmental problems which determines whether or not the problem ends up on the policy agenda.

The participants at the international forum on Science for Public Policy held at IIASA in 1984 also discussed how an environmental issue winds up on the policy agenda of nations and international organizations. While the members of Panel 3 advised others to be careful of oversimplifying the agenda-setting process, they did search for fundamental structural features of an environmental problem which seem to influence whether or not it gets onto the policy agenda. Two of the structural features are **spatial structure** and **temporal structure.**

The spatial structure of an environmental problem describes whether the problem is local, regional, or global in character.[30] For each of these spatial scales, the panel observed, different communities (scientific, political, and layperson) will need to be involved. Through the descriptors "transnational", "land area or resource at risk", and "spatial extent", the KSG taxonomy can provide the user with useful knowledge about which communities he or she should encourage to get involved with each environmental problem. If a problem scores a "9" on transnational, the policy maker may be alerted to the fact that the problem will require action by individuals who have access to the international negotiating context.

The temporal structure of a problem refers to whether, "...policy relevant consequences are felt immediately or only predicted for the distant future."[31] When environmental issues are predicted for the distant future, scientists are put under pressure to offer quick accurate advice--advice they cannot always provide. The KSG descriptors that characterize the future effects of a problem can alert policy makers to the difficult scientific questions he or she may encounter and to which communities to turn for advice immediately.

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[30] Panel 3. Science for Public Policy, pg. 247.

[31] Panel 3. Science for Public Policy, pg. 247.

RECOMMENDATIONS:

-Pay close attention to the KSG model's descriptors, "spatial extent", "land area", "transnational", and the "future" descriptors.

Part V: Conclusions and Recommendations

The creators of the KSG hazard characterization taxonomy intended this taxonomy to be a tool for helping policy makers prioritize the environmental risks their society faces. After reviewing existing taxonomies that attempt to perform similar functions, testing the KSG taxonomy on the United States and India, and evaluating the taxonomy, we have the following recommendations:

(1) In its final form, the KSG taxonomy can be used to characterize successfully the international environmental problems attempted in the case studies.

The taxonomy has the most difficulty in scoring natural resources and natural environmental hazards. However, the overall profiles of the United States and India seem accurate.

(2) The KSG taxonomy should incorporate the following modifications:

a. Omit the descriptors "intentionality", "transgenerational","recurrence", and "magnitude of future consequences".

b. Provide new definitions of standards for "delay", "spatial extent", "concentration", and "natural ecosystem impacts"

c. Rewrite the problem chains for Animal Habitat (9) and Stock of Wildlife (23) into a single problem chain called Species Diversity.

(3) A policy maker using the KSG taxonomy should follow these recommendations:

a. Attempt different "weighting" schemes in order to help players in the political debate recognize the value judgments they make.

b. Expect public opinion polls to differ from the KSG results and use various mechanisms for including laypersons in the resolution of the policy debate.

c. Use uncertainty in a positive manner by allowing it to point out areas that require more scientific research and to induce others to help create a consensus building process.

d. Pay attention to the KSG descriptors that indicate whether a problem is local, regional or global and the descriptors that indicate whether future generations are affected.

A METHODOLOGY FOR THE COMPARATIVE ASSESSMENT OF ENVIRONMENTAL PROBLEMS

by

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A METHODOLOGY FOR THE COMPARATIVE ASSESSMENT OF ENVIRONMENTAL PROBLEMS

1. INTRODUCTION

Global environmental problems such as ozone depletion and the greenhouse effect have been capturing headlines and the attention of high level international meetings over the past few years, and in the case of ozone depletion have already resulted in a protocol for reducing substances that deplete the ozone layer. In addition, more local and regional environmental problems such as waste disposal, renewable resource depletion and drought have been an important aspect of public and governmental debates and action. These diverse environmental problems have competed for a spot on the political agenda, for the attention of regulatory agencies, and for the limited funds allocated to the solution of environmental problems. In the face of limited public and governmental attention and resources, it would be useful to have a method for performing a comparative assessment of the relative hazardousness of the diverse set of environmental problems which are now facing some or all nations around the world.

To this end, the causal taxonomy presented in this paper has been developed for the dual purpose of comparing the environmental problems within a country, and comparing the ranking of environmental problems of different countries. We imagine that this tool will be used in two different ways. The first is by a national level decision-maker who is interested in setting the environmental policy agenda within her country. In this case, we expect this tool to provide a similar function to the EPA's assessment, "Unfinished Business" (U.S. EPA, 1987). The second application is by someone involved in finding solutions for international environmental problems who wants to know the relative importance of problems not only in her own country, but in other countries as well.

Environmental policy-making requires the two distinct but interrelated tasks of hazard assessment and hazard management.[1] The tool described in this paper contributes to the task of hazard assessment and was not developed as a tool for the management of a particular environmental problem. For example, while it may highlight that water quality is a significant problem in a given country, it does not tell you the management options for alleviating the problem, whether they are easy

[1] In choosing to use the phrase "hazard assessment and hazard management" rather than "risk assessment and risk management", we are drawing on the distinctions between these concepts that were made by Hohenemser et al. (1985). "We define hazards as threats to humans and what they value and we define risks as conditional probabilities of experiencing harm." Thus, in this hazard assessment project, risk assessment can be considered an important part, but not the totality, of the effort.

or hard to implement, and how much they would cost. In this sense, this effort is similar to the EPA's "Unfinished Business" in that it focuses on the hazard or harm and in so doing does not perform the following tasks: (1) evaluate the economic or technical controllability of the risks, (2) quantify or list the benefits to society from the activities which cause the environmental risk, (3) look at existing governmental efforts which have ameliorated or exacerbated an environmental problem, (4) evaluate qualitative aspects important to the publics' perception of risk including voluntariness, familiarity, or equity (U.S. EPA, 1987). Having distinguished this as a tool for hazard assessment, it is important to note that the organizing framework was designed to facilitate the interaction of the dual tasks of hazard assessment and hazard management, as discussed in the next section.

2. METHODOLOGICAL UNDERPINNINGS

The methodology employed in this effort has built extensively on the ideas presented in Perilous Progress (Kates, et. al., 1985).[2] This research effort developed a causal structure which provided a framework for thinking about hazard assessment and hazard management. This structure described hazards in terms of the relationship between human needs, human wants, technological choices, initiating events, releases of materials or energy, exposure to materials or energy, and human and biological consequences. This causal structure provided the framework for the development of a causal taxonomy for the comparative analysis of technological hazards. This taxonomy, presented in Figure 1, is composed of indicators which described common differentiating characteristics of technological hazards at each stage in the causal structure.

Two aspects of this research make it particularly valuable as a hazard assessment framework. First is its incorporation of the multi-dimensional nature of the hazardousness of technological problems and the risks posed by these problems into its methodology. Early work on risk assessment was based heavily on human mortality as the measure of harm (as reviewed by Hohenemser, et al., 1983). More recent studies have demonstrated that while experts often still rely on mortality in their relative rankings of environmental risk, public perception of riskiness is dependent not only on mortality, but also on factors such as controllability, knowledge, and dread (Slovic, et al., 1985). This framework captures other relevant and measurable characteristics of hazards.

Secondly, by elucidating the sequence of events that create a hazard, the causal taxonomy provides a link between the functions of hazard assessment and hazard

[2]This work also draws on unpublished work by Gordon Goodman which was performed around the same time as Perilous Progress. Goodman's effort was specifically aimed at evaluating environmental hazards, and uses many of the same descriptors as those found in Perilous Progress.

management. As shown in Figure 2 for the example of the hazard posed by a fireplace, each step in the causal chain provides a potential point of intervention. While the current effort will not explore management specifically, the use of a causal framework provides hazard information in a form relevant to management, and makes the development of a management assessment a complimentary next step.

Our effort differs from the work in Perilous Progress in two important ways which have required the development of a somewhat different taxonomy.

1. A focus on environmental problems. This requires the inclusion of pollution based problems (technological hazards), renewable resource depletion, and natural environmental hazards. We have thus developed a taxonomy more appropriate to this range of problems and defined our problems at a different point in the causal chain.[3] In addition, the focus on environmental problems has led us to develop an expanded set of consequence descriptors. In this sense, we are drawing on the EPA's Unfinished Business (1987) which focused exclusively on the consequences of environmental problems, including assessments of human health and morbidity in terms of cancer, and non-cancer risks, ecological risks, and welfare risks.

2. Development of a tool for hazard assessment within a country as well as for international comparisons. This has resulted in scales which are based on a percentage of a country's population, GNP, etc. In addition, due to the international nature of some environmental problems, descriptors were developed to distinguish between the source nation and the nation experiencing consequences.

3. A CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

The causal taxonomy of environmental problems developed for this assessment is shown in Figure 3. This taxonomy is based on a common conceptual model of human impacts on the environment (e.g. see Schelling, 1983). Based on this taxonomy, each environmental problem we have identified consists of a chain of events: human activities, changes in material and energy fluxes, changes in valued environmental components, exposure, and consequences for humans and that which we value.

[3]While CENTED's effort defined their hazards in terms of a single technology and its release of a single material, often several technologies and several different chemical releases are part of a single environmental problem. Thus, we have defined our problems in terms of the valued environmental component as will be described in Section [ ].

The taxonomy starts with the "**human activities**" which are the initial sources of changes in the environment. These activities are defined by both the choice of technology and the level of activity.[4]

These human activities lead to measurable changes in chemical flows or in other physical or biological components of the environment, which are together described as "**changes in the material fluxes**". In the case of pollution based environmental problems, this refers to an increase (or decrease) in chemical constituents. In the case of renewable resource depletion, this describes a decrease (or increase) in the stock of a plant or animal. And for natural hazards, this describes a change in the accustomed or usual flow of materials or energy, noting that the accustomed flow may be zero.

Changes in these material fluxes then lead to changes in "**valued environmental components**" which are most simply described as those attributes of the environment which humans value. In general, we value these components not in and of themselves (although this point would be debated by the deep ecologists), but because changes in them lead to undesired "consequences for humans and that which we value".

"**Exposure**" is the pathway by which changes in VECs cause consequences. This would include, for example, in the case of human health: inhalation, ingestion, and dermal contact.

"**Consequences for humans and that which we value**" include increased risks to human life and human health, to ecological systems, and to human welfare (productivity and material losses). In this taxonomy, we have included loss of species as a consequence of value to humans, and thus will not define it separately as an environmental problem. This is because changes in many different valued environmental components can lead to the loss of species, and thus it is not a single environmental problem.

As an example in the application of this taxonomy, the environmental problem of stratospheric ozone depletion is shown in Figure 4. This figure demonstrates that in practice the taxonomy may be expanded to include more than one stage of any of the components of the taxonomy. For example, in the case of ozone depletion, a change in one environmental constituent (increased CFC's in the stratosphere) leads to a change in another (decreased ozone in the stratosphere). The example of ozone depletion also shows that in practice, the taxonomy may look more like a "pitchfork" than a simple chain. In this case, changes in the concentration of several

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[4]This category encompasses a number of aspects which are looked at in more detail in the CENTED work, including human needs, human wants, and choice of technology. For a management tool, these would need to be separated, as describe different possibilities for intervention. As way of evaluating relative hazardousness, can be lumped together.

ozone depleting gases lead to a decrease in ozone in the stratosphere, and the change in the valued environmental component of UV radiation on the earth's surface leads to several different consequences.

4. THE DESCRIPTORS FOR A CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

For each stage in this causal taxonomy, we have developed several "descriptors" which characterize an environmental problem at the given stage. These are summarized in Table 1. As noted in the table, several of these are identical or similar to those used in Perilous Progress. Another is taken from work by Goodman. In addition, several of the consequence indicators were inspired by EPA work. The definition, measurement scales, and application of these descriptors is provided in more detail in Appendix A.

Similar to those used in Perilous Progress, many of our descriptors have logarithmic scales, in some instances in base 2 and in others in base 10. This is because both the uncertainty of measurements and human perception are in this range.

In scoring the descriptors, our approach is to evaluate these problems from the perspective of a self-interested country. Thus, when evaluating a specific problem it will be that problem as experienced by the nation to which the framework is being applied. This perspective is not meant to imply that a nation does not care about how severe a problem is for other nations; information about other nations can be generated by applying the framework to the nations of interest.

5. DEFINITION OF ENVIRONMENTAL PROBLEMS

The criteria for a scheme for defining the environmental problems were threefold: (1) understandable and meaningful to policy-makers and other "non-specialists", (2) comprehensive, including all the major environmental problems faced by all nations, and (3) based on the causal taxonomy, and in this sense internally consistent and theoretically justifiable.

With this in mind, we have chosen to identify our list of problems by the change in a valued environmental component (VEC), and not by some other point in the causal chain. This is an important decision. The reason for this choice is best described by walking through an example such as climate change, illustrated in Figure 5. It is not the human activity of, for example, fuel burning, that is the problem. In fact, such activities represent benefits to society as well as sources of environmental problems. Likewise, the change in the carbon cycle is not of concern to us except as it changes a component of the environment we care about, in this case, the thermal radiation budget. Moving further down the causal chain, exposure is the link between changes in environmental components and the consequences we care about. It holds no promise as a unique definition of an environmental problem.

Likewise, consequences for humans and that which we value are not unique definitions of a single problem.[5]

The list of environmental problems is given in Table 2. This list includes pollution, natural resource depletion, and natural disaster. Although these are often thought of as very different types of problems, it is crucial to include them all in this study in order for this tool to be useful. Each of these 3 types of environmental problems is likely to be amongst the most important for some group of countries. These problems are described in terms of their causal structure in Appendix B.

6. CONCLUSION/APPLICATIONS

This paper represents an effort to develop a methodology for comparing environmental problems within and across countries. It is based on a causal structure of environmental hazards which draws heavily on previous work in the field of hazard assessment. The usefulness of this methodology can only be evaluated through application. A companion paper describing the application of this methodology to the U.S. will evaluate the first effort of application of this framework (to be available on February 14). Studies of India, Kenya, and Sweden are also underway.

[5]Having gone through this rather lengthy explanation, it is important to point out that the contenders for how to define environmental problems are generally to define them either by the VEC in question, or the human activity leading to that VEC. While the majority of environmental assessments look at changes in a single or small group of VECs, there are important arguments for basing assessments on human activities. One of the strengths of the Bruntland commission was to argue for the need to consider environmental changes as part of the planning in all sectors of the economy, i.e. for all types of human activity. Nonetheless, for ranking the severity of environmental problems faced by a given country, defining the problems by VECs is more useful. Beanlands and Duinker (1983) have shown that the most useful environmental impact assessments are those based on a clearly defined set of VECs.

TABLE 1, page 1
THE DESCRIPTORS

TECHNOLOGY DESCRIPTOR

1. Intentionality. Measures the degree to which technology is intended to harm.

MATERIAL FLUX DESCRIPTORS

2. Spatial Extent. Measures the spatial extent of a single release for which there is a significant change in flux.

3. Concentration. Measures the degree to which a change in the flux of materials is above natural background or sustainable levels.

4. Persistence. Measures the time period over which the initial release of materials causes an altered flux which has measurable consequences to human health, ecosystems and material welfare.

5. Recurrence. Measures the time period over which the minimum significant release of event which alters material fluxes recurs.

6. Rate of Change in material flux. This measures the current rate at which the material flux is growing or diminishing.

EXPOSURE DESCRIPTORS

7. Population at risk. Measures the percent of population within a country that are exposed or potentially exposed.

8. Land area or resource at risk. Measures the percent of land area within a country that is exposed or potentially exposed.

9. Delay. Measures the delay time between the release or altering of materials and the occurrence of consequences.

TABLE 1, page 2
THE DESCRIPTORS

CONSEQUENCE DESCRIPTORS

10. **Human mortality (current annual).** Measures the average annual percent of population that dies from the hazard.

11. **Human morbidity (current annual).** Measures the average annual percent of population that becomes significantly ill from the hazard.

12. **"Natural" ecosystem impacts (current annual).** Describes the impacts to "natural" ecosystems.

13. **Welfare effects: Material and productivity losses. (current annual).** Measures the average annual loss of materials and productivity.

14. **Transgenerational.** Measures to number of future generations which suffer consequences due to human activities today.

15. **Transnational.** Describes the nations which cause the consequences.

16. **Commitment to future human health consequences - severity of harm.** Describes the commitment to human health consequences for succeeding generations from

17. **Commitment to future ecosystem consequences - severity of harm.** Describes the commitment to ecosystem consequences for succeeding generations from human activities today.

18. **Magnitude of Future Consequences.** Describes the magnitude of commitment to succeeding generations from human activities today.

TABLE 2: LIST OF ENVIRONMENTAL PROBLEMS

ENVIRONMENTAL HAZARDS

WATER

1. Freshwater quality - biological contaminants
2. Freshwater quality - metals and toxics
3. Freshwater quality - nutrients and dissolved oxygen (eutrophication)
4. Freshwater quality - sedimentation
5. Ocean water quality

LAND (the Lithosphere)

6. Soil salinity, alkalinity, waterlogging
7. Soil productivity, desertification
   (soil erosion, land degradation, soil compaction)
8. Quantity of arable land (loss of arable land to urbanization)

BIOTA

9. Quantity and quality of animal habitat
10. Pure food supplies (non-toxicity of food)
11. Rate of gene mutation (cryptic spread of mutant genes)

ATMOSPHERE

12. Ultraviolet energy absorption (stratospheric ozone depletion)
13. Thermal radiation budget alteration (climate change)
14. Acidification (acid rain)
15. Photochemical oxidant formation (smog, elevated tropospheric ozone)
16. Concentration of toxins (Hazardous and toxic air pollutants)

THE HUMAN ENVIRONMENT

17. Indoor air quality - radon
18. Indoor air quality - non-radioactive pollutants
19. Exposure to chemicals (including biological pathogens) in the workplace
20. Exposure to radiation (other than radon)
21. Accidental chemical releases

RENEWABLE RESOURCES

22. Stock of fisheries
23. Stock of wildlife
24. Forestry reserves
25. Groundwater resources

NATURAL ENVIRONMENTAL HAZARDS

26. Floods
27. Droughts
28. Pest epidemics

Figure 1: The causal structure of technological hazards.

from Kates et al., 1985. p. 29

Figure 2: Hazard sequence for fireplace. Illustration of range of possible control interventions.

from Kates et al., 1985. p. 69.

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APPENDIX A
THE DESCRIPTORS[6]

Generic Issues Regarding Scoring:

Summing: Often parts of a problem would score differently if divided into separate components. For example, in the case of Stratospheric Ozone Depletion, persistence of some CFC's are 10 years and others are 110 years. There are three different methods of summing that are used in the scoring of different descriptors:

1. Total: Adding up over all aspects.
2. Highest Significant Score: Give the highest score for which a significant portion of the problem would score. Define significant portion as about 20%.
3. Weighted Average: Take a weighted average over all aspects of the problem.

TECHNOLOGY DESCRIPTOR

1. Intentionality.

Measures the degree to which technology is intended to harm.

score	categorical definition
3	Not intended to harm living organisms
6	Intended to harm nonhuman living organisms
9	Intended to harm humans

Notes on scoring: We would expect a score of "Intended to harm humans" only in the rare cases of significant environmental effects from war or from the preparation for war. All natural resource depletion and natural hazards will have a score of 3.
Summing rule: Highest significant score.

[6]Many of these descriptors were inspired by the work of Hohenemser, et al., EPA, and Goodman. The following descriptors are identical to those used by Hohenemser, et al.: Intentionality, Persistence, Recurrence, and transgenerational. Several others are modifications in scale or interpretation, but nonetheless quite similar to those used by Hohenemser, et al., including: Spatial Extent, Concentration, Population at Risk, Delay, and Human Mortality. The scale for spatial extent is the same as that used by Goodman, and the rate of change in material flux is similar to Goodman's descriptor of "harm burden growth".

MATERIAL FLUX DESCRIPTORS

2. Spatial Extent

Measures the spatial extent of a single release for which there is a significant change in flux. In other words, this measures the distance from a source in which a single release contributes to a change in flux. The quantitative scale is based on lineal dimensions, the categorical scale on common geographical units.

score	Distance Scale	categorical definition
1	< 10 km	Small Region
3	10 - 100 km	Region
5	100 - 1000 km	Subcontinental
7	10^3 - $_4 10^4$	Continental
9	> 10	Global

Notes on scoring: One of our concerns here is to distinguish between national, multi-national within a region, and global. A score of "1" or "3" will be within a nation for all countries. While theoretically, a score of "5" could be within a nation for the largest nations, we have not been able to think of an example where this is the case (e.g. acid rain in the U.S., Canada, U.S.S.R., and China would be scored "5", and would be a multi-national regional problem). (Thus, it is safe to say that a score of "1" or "2" indicates the problem is within a nation, while a score of seven or over indicates it is multinational. An exception to this is that a score of 3 will be continental for Austrailia.)

Summing rule: Highest significant score.

3. Concentration.

Measures the degree to which a change in the flux of materials is above natural background or sustainable levels. The scale is based on the ratio R.

For pollution: R is defined as the concentration averaged over the spatial extent of the pollutant release divided by the natural background level.
For resource depletion: R is defined as the rate of harvesting or extraction divided by the maximum sustainable yield.
For natural disasters: R is defined as the concentration average over the release scale divided by the average, accustomed or usual flux.

Score	Concentration Scale
1	R < 1
2	R = 1
3	1 < R < 10
4	10 < R < 100
5	100 < R < 1000
6	1000 < R < 10,000
7	$10^4 < R < 10^5$
8	$10^5 < R < 10^6$
9	$10^6 < R$

Notes on scoring: When measuring concentration, use the change in flux closest to the human perturbation. For example, with stratospheric ozone depletion, measure chlorine flux and not change in ozone concentrations.
Summing rule: Weighted average

4. Persistence.

Measures the time period over which the initial release of materials causes an altered flux which has measurable consequences to human health, ecosystems and material welfare.

Score	Time Scale
1	< 1 min.
2	1 min - 1 hr.
3	1 hr - 1 day
4	1 day - 1 week
5	1 week - 1 month
6	1 month - 1 year
7	1 year - 10 year
8	10 years - 100 years
9	> 100 years

Notes on scoring: For renewable resource problems, this is defined as the time until an equal level of productivity is reached after the current perturbation. For pollutants, this is the time until the background level is reached in the environment after the current releases of pollutants.
Summing rule: Highest significant score.

5. Recurrence.

Measures the time period over which the minimum significant release of event which alters material fluxes recurs. Use the scale for Persistence.

Notes on scoring: Within the pollution and resource depletion category, we will not expect to get a large range of scores here as most of the activities we are considering are continual, and will therefore be ranked "1". However, accidental releases, chemical or nuclear accidents, and natural disasters will rank differently.

Summing rule: Highest significant score.

6. Rate of Change in material flux.

This measures the current rate at which the material flux is growing or diminishing.

Score	Doubling/Halving Time	Per cent increase per year
	halving time	
1	< 10 years	< -7.0
2	10 - 20 years	-7.0 to -3.5
3	20 - 40 years	-3.5 to -1.7
4	> 40 years	<- 1.7
5	no detectable change	0
	doubling time	
6	> 40 years	< 1.7
7	20 - 40 years	3.5 to 1.7
8	10 - 20 years	7.0 to 3.5
9	< 10 years	> 7.0

Notes on scoring: For pollution, this measures the current rate of change of the releases of material to the environment. For resource depletion, it measures the rate of change of harvesting or extraction. For natural disasters, this measures the rate of change of occurrence, as in more floods, more days of drought, etc.

In the case of transnational problems, this measures the rate of change in the flux of all nations which contribute to the material flux in a way that effects the country in question.

Summing rule: Weighted average.

EXPOSURE DESCRIPTORS

7. Population at risk

Measures the percent of current population within a country that are exposed to the change in VEC.

score	% of population
1	< 1%
3	1% - 10%
5	10% - 30%
7	30% - 70%
9	> 70%

Summing rule: Total.

8. Land area or resource at risk

Measures the percent of land area within a country that is currently exposed to the changed VEC.

score	% of land area
1	< 1%
3	1% - 10%
5	10% - 30%
7	30% - 70%
9	> 70%

Notes on scoring: For atmospheric pollution problems, this measures the percent of the nation which experiences this problem. For water pollution problems, this measures the percent of the water resource affected. For resource depletion problems, this measures the extent of the resource affected. For natural disasters, this measures the percent of the nations land area which experiences this problem.

Summing rule: Total.

9. Delay

Measures the delay time between the release or altering of materials and the occurrence of consequences. Use the scale for Persistence.

Summing rule: Highest significant score.

CONSEQUENCE DESCRIPTORS

10. Human mortality (current annual)

Measures the average annual percent of population that dies from the hazard.

score	% of population
1	$< 10^{-6}$
2	10^{-6} - 10^{-5}
3	.00001 - .0001
4	.0001 - .001
5	.001 -.01
6	.01 - .1
7	.1 - 1
8	1% - 10%
9	> 10%

Summing rule: Total.

11. Human morbidity (current annual)

Measures the average annual percent of population that becomes significantly ill from the hazard. Significantly ill is defined as a permanent injury or injury that interferes with normal activity. Use the scale for human mortality.

Summing rule: Total.

12. "Natural" ecosystem impacts (current annual)

This describes the impacts to "natural" ecosystems. This does not include ecosystems which are managed predominantly for the purpose of harvesting food or materials. (i.e. farmland).

score	categorical definition
3	No significant effect
6	Significant declines in productivity or decrease in species richness
9	Extinction of significant species

Summing rule: Total.

13. Welfare effects: Material and productivity losses. (current annual)

Measures the average annual loss of material and productivity. For a nation with a well developed commercial economy, this will measure commercial losses as a percent of GNP. For an environmental problem in a nation with a largely non-market economy where damages occur in the non-market portion of the economy, this measures the productivity loss and property damage as a % of total productivity and property.

Damages to be included in this measure are: material damages (damages to capital stock, damages to public and commercial property), crop losses, loss of recreation, resource damages, water supply degradation, and aesthetics. Monetary values of human health care costs or human productivity losses are not included in this category, as they are valued separately above.

score	% of GNP (or productivity plus property)
1	$< 10^{-6}$
2	10^{-6} - 10^{-5}
3	.00001 - .0001
4	.0001 - .001
5	.001 -.01
6	.01 - .1
7	.1 - 1
8	1% - 10%
9	> 10%

Summing rule: Total.

14. Transgenerational

Measures to number of future generations which suffer consequences due to human activities today. Assumes no change in trends of management activities to ameliorate consequences. I.e., use a business as usual scenario.

score	categorical definition
3	Hazard affects the current generation only.
6	Hazard affects children of the current and the current.
9	Hazard affects more than one future generation.

Notes on scoring: It is important to note that the assumption here is not "no management change", but rather "no change in trends of management". This means, for example, that if a nation has been improving its sewage treatment at a certain rate, we can assume this rate of improvement will continue. For management activities that have been holding steady, we can assume this won't change. To the extent that a nation has a credible action plan for ameliorating a problem, this should be taken into consideration.

Summing rule: Highest significant score.

15. Transnational

Describes the nations which cause the consequences.

score	categorical definition
3	Consequences are caused mainly by own activities
6	Consequences are caused by neighbors activities and own activities
9	Consequences are caused by activities around the world

Summing rule: Highest significant score.

16. Commitment to future human health consequences - severity of harm.

Describes the commitment to likely human health consequences for succeeding generations from human activities and decisions today. Assumes no change in trends of management activities to ameliorate consequences. I.e., use a business as usual scenario.

score	categorical definition
1	nuisance or no harm
3	slight harm (occasional sickness - lost work days
5	significant harm (prolonged illness)
7	severe harm (chronic and lethal toxicity, disablement and death)
9	Genotoxic lethality (recessive lethal mutants spreading through succeeding generations)

Notes on scoring: See notes under descriptor #14.

Summing rule: Highest significant score.

17. Commitment to future ecosystem consequences - severity of harm

Describes the commitment to ecosystem consequences for succeeding generations from human activities today. Assumes no change in trends of management activities to ameliorate consequences. I.e., use a business as usual scenario.

score	categorical definition
3	No significant effect
6	Significant declines in productivity or decrease in species richness
9	Extinction of significant species

Notes on scoring: See notes under descriptor #14.

Summing rule: Highest significant score.

18. Magnitude of Future Consequences.

Describes the magnitude of commitment to succeeding generations from human activities today. Assumes no change in trends of management activities to ameliorate consequences. I.e., use a business as usual scenario.

score	categorical definition
3	Future consequences are significantly smaller than current consequences
6	Future consequences are of the same magnitude as current consequences
9	Future consequences are greater than current consequences

Notes on scoring: See notes under descriptor #14.

Summing rule: Total.

APPENDIX B
ENVIRONMENTAL PROBLEMS

WATER
Note: Freshwater is defined as both surface water and ground water.

1. Freshwater Quality - Biological Contaminants

Human Activities: Human and animal waste disposal.

Changes in material fluxes: levels of bacteria, viruses, and parasites in surface and/or groundwater.

Changes in Valued Environmental Components: Reduction in quality of freshwater supplies. Particularly relevant for drinking water.

Exposure: Ingestion of water. Ingestion of contaminated food. Dermal contact.

Consequences: Results in human mortality and human morbidity. Diseases carried include: diarrhea, cholera, sleeping sickness and guinea worm infestation. Loss of recreation through closing of waterways, beaches, etc.

2. Freshwater Quality - Metals and Toxics

Human Activities: The use of herbicides and pesticides. Fossil fuel combustion (deposition from the atmosphere into water, or onto land surfaces and then run-off). Industrial activities including releases of chemicals to the air, waste disposal, accidental releases and underground storage. Mining. Consumer (municipal) waste disposal. Irrigation drainage.

Changes in material fluxes: Increased pollutants in surface waters and groundwater. Toxic chemicals including heavy metals, inorganic compound and volatile organic compounds from urban run-off, industrial sources and mining. Toxic chemicals from herbicide and pesticide use.

Changes in Valued Environmental Components: Reduction in quality of water supplies. Increased toxicity of water.

Exposure: Human exposure through ingestion of water and contaminated food, and dermal contact. Aquatic life exposed to increased pollutants in water.

Consequences: Results in human mortality and human morbidity. Some pollutants are carcinogenic or mutagenic. Damage to aquatic ecosystems such as reproductive deformities to animals which depend on these aquatic ecosystems, including birds and mammals. Crop losses from decreased biological productivity due to contaminated irrigation water.

3. Freshwater Quality - Nutrients and Dissolved oxygen (Eutrophication)

Human Activities: Use of fertilizers in agriculture. Animal husbandry. Forest clearing. Municipal waste disposal.

Changes in material fluxes: Increased nitrates in water from fertilizers, animal husbandry, forest clearing, and municipal wastes. Increased phosphates in water from fertilizers and municipal waste disposal.

Changes in Valued Environmental Components: Initial changed VEC is increased nutrient loading in water. This in turn leads to increased algal growth, which leads to decreased clarity and increased particulate organic levels in the water, which leads to the settling of particulate organic material into deep water where they die, which leads to overabundant bacteria which consume oxygen and produce hydrogen sulfide, which leads to a decrease in oxygen levels in deep water. In summary, there are two key changed VEC's: eutrophication (lack of oxygen) and increased microbes/bacteria concentration.

Exposure: To fish, through inhalation, lack of oxygen. For vegetation and other shellfish, ingestion of bacteria.

Consequences: Unsafe levels of nitrates cause methemoglobinemia in infants, hypertension in children, gastric cancer in adults and fetal malformations. Nitrates may be carcinogenic or mutagenic. In the case of eutrophication, fish die or are displaced. Increased bacterial concentrations lead to contaminated fish. This leads to losses of the commercial fishing industry. Also losses to tourism.

4. Freshwater Quality - Sedimentation

Human Activities: Agricultural practices leading to erosion from cropland, silviculture practices or deforestation leading to erosion from forestland (or formerly forested land), animal husbandry leading to erosion of rangeland, construction activities,

Changes in material fluxes: Increased sediments in river water, increased sedimentation in waterways.

Changes in Valued Environmental Components: Reduction in quality of water supplies. Increased toxicity of water. Decreased navigatability of waterways.

Exposure: Through ingestion, through use of riverways for transportation.

Consequences: Harm to aquatic life. Decreased river navigation. Destruction or decreased efficiency of hydroelectric projects.

5. Ocean Water Quality (Coastlines, coastal wetlands)

Human Activities: Off-shore oil drilling, oil transport, shipping in general. Waste disposal including sewage, industrial wastes and consumer, commercial and public wastes. Discharges of pollutants from rivers, direct coastal outfalls, and coastal urban and agricultural runoff.

Changes in material fluxes: Increased concentrations of oil, plastics, microbial/organic concentrations, and toxic chemicals.

Changes in Valued Environmental Components: Decreased ocean water quality, increased ocean water toxicity. Disruption of marine food chains.

Exposure: Entanglement by marine life. Ingestion by marine life including: shellfish, fish, marine mammals, birds, plankton, algae, etc, sometimes several steps removed on the food chain. Ingestion of contaminated seafood by humans. Dermal contact. Visual contact.

Consequences: Human health and morbidity from exposure to toxins (especially through contaminated seafood); including carcinogenic and mutagenic effects. Ecosystem damage, especially local effects from locally high concentrations. Loss of recreation and loss of food supplies from ocean.

LAND (the Lithosphere)

6. Soil salinity, alkalinity, waterlogging

Human Activities: Irrigation.

Changes in material fluxes: Irrigation water unused by plants or not absorbed in the air percolates down to the underground water table. Water table rises resulting in this underground water being pulled to the surface by capillary action and evaporating. The evaporation results in increased salts and alkaline. Also, a rising water table deprives the plant roots of needed air (waterlogging).

Changes in Valued Environmental Components: Increased salinity, alkalinity and waterlogging leading to decreases in soil productivity.

Exposure: For humans, decreased food supplies. For crops, exposure to changed soil conditions.

Consequences: Decrease in productivity of land or complete loss of productive land, leading to crop losses. This may cause hunger which in turn leads to increased human morbidity and mortality.

7. Loss of soil productivity, desertification (soil erosion, land degradation, soil compaction)

Human Activities: Land clearing (deforestation, burning or harvesting). Cultivation of marginal lands. Livestock grazing (overgrazing). Cultivation techniques such as furrowing, mechanization, and use of fertilizers.

Changes in material fluxes: Degradation or loss of vegetative cover which in turn leads to: increased soil erosion, soil desiccation, soil compaction, reduction of soil organic matter and plant nutrients, reduction of biological activity.

Changes in Valued Environmental Components: Reduction in soil productivity which leads to a reduction in the food supply (crop losses).

Exposure: For humans, decreased food supplies. For crops, exposure to changed soil conditions.

Consequences: Reduction in crops and livestock produced on land. This may casue hunger which in turn leads to increased human morbidity and mortality.

8. Quantity of arable land (loss of arable land to urbanization)

Human Activities: Urbanization.

Changes in material fluxes: Land is removed from agricultural production and put to use for human settlements, industry and commercial purposes.

Changes in Valued Environmental Components: Loss of arable land which leads to a reduction in the food supply.

Exposure: HUman exposure to reduced food supply.

Consequences: Productive losses in agriculture. This may cause hunger which in turn leads to increased human mortality and morbidity.

BIOTA

9. Quantity of Animal Habitat

Human Activities: Physical reduction of habitat through deforestation, wetland conversion, building of dams.

Changes in material fluxes: Loss of forests, wetlands, other environments.

Changes in Valued Environmental Components: Quantity and quality of animal habitat.

Exposure: Animals exposed to lack of suitable habitat.

Consequences: Decline in animal populations. Loss of species. Loss of contribution species make to agriculture, medecine, and industry.

10. Purity of Food Supplies (non-toxicity of food)

Human Activities: Use of herbicides and pesticides in agriculture; disposal of industrial chemicals, radionuclides, inorganic compounds.

Changes in material fluxes: Increase in herbicides, pesticides and toxins in soil and on food.

Changes in Valued Environmental Components: Decrease in purity of food or increase in toxicity of food.

Exposure: Ingestion.

Consequences: Increased cancer and other health problems in humans. Possible damage to wildlife that consumes human foods.

11. rate of gene mutation (Cryptic spread of mutant genes)

Human Activities: Ionizing radiation, dominant source being medical exposure. Use of pharmaceuticals. Mutagenic chemicals in the environment from industry, agriculture, and fossil fuel combustion.

Changes in material fluxes: Increase in altered genes which determine health of future generations.

Changes in Valued Environmental Components: Ability to produce healthy offspring.

Exposure: Can be occupational, medical, general environmental, or accidental.

Consequences: Increased morbidity and mortality in offspring. Cancer, degenerative diseases (mental and physical disabilities), fetal congenital malformations.

ATMOSPHERE

12. Ultraviolet energy absorption (stratospheric ozone depletion)

Human Activities: Manufacture, use and disposal of halocarbons, including chlorofluorocarbons (CFCs), halons, chlorinated hydrocarbons, and chlorinated carbons. These substances are used in the manufacture of foam for insulation and packaging, as a propellent, as a heat transfer fluid in heating and cooling systems, as solvents, especially in the electronics industry, and in fire extinguishers.

Changes in material fluxes: Increased concentration of CFCs, halons, chlorinated hydrocarbons, and chlorinated carbons. Through a series of chemical reactions, this leads to a decrease in the concentration of ozone (O^3) in the stratosphere.

Changes in Valued Environmental Components: Increased ultraviolet (UV) radiation on the earths surface. A reduction in the ozone shield leads to more radiation reaching the earth's surface.

Exposure: UV radiation contact on skin, eyes, ecosystems.

Consequences: Increased human mortality from malignant melanoma skin cancer. Increased human morbidity from non-melanoma skin cancer, and eye disorders, including cataracts and acute photokeratitis (snow blindness). Suppression of immune response system of humans and animals, slower growth and higher mortality among plant and animals. May aggravate nutritional deficiencies, infectious diseases, and autoimmune disorders. At high levels, may reduce crop productivity. Causes decrease in fecundity, growth, survival and other functions of aquatic organisms, and thus affects ocean food chain. Accelerated degradation of some plastics and paints. Crop productivity losses due to UV radiation, and secondary losses due to increased tropospheric smog.

13. Thermal radiation budget alteration (climate change)

Human Activities: Fossil fuel production, distribution, and combustion. Production, consumption and disposal of halocarbons (CFCs, halons, and chlorocarbons). Wetland rice cultivation. Livestock husbandry. Use of nitrogenous fertilizers in agriculture. Landfilling of wastes. Land use modification including deforestation, biomass burning and wetland conversion.

Changes in material fluxes: Increases in several chemical constituents in the stratosphere, including: Carbon dioxide (CO_2) from fossil fuel consumption, deforestation and biomass burning. Halocarbons. Methane (CH_4) from landfills, fossil fuel production and distribution, wetland rice cultivation livestock husbandry and biomass burning. Nitrous oxide (N_2O) from fossil fuel consumption, use of nitrogenous fertilizer, deforestation and biomass burning.

Changes in Valued Environmental Components: Thermal radiation budget alteration leading to climate change. This in turn will lead to several other changes in key environmental components, including: temperature, sea level, precipitation, changes in storm patterns including frequency and severity, direct solar radiation, evapotranspiration, soil moisture, and run-off.

Exposure: Humans and ecosystems exposed to changed climate.

Consequences: Consequences are likely to vary significantly from one region to another. They include: Severe disruptions of natural ecosystems, with species loss. Losses (or gains) to agricultural productivity. Disruptions to human settlements and infrastructures, including property losses and loss of electric power. Loss of life. Loss of freshwater supplies.

14. Acidification (acid rain)

Human Activities: Fossil fuel combustion and use. Industrial activities including smelters, paper manufacture.

Changes in material fluxes: Increased sulfur oxides (SO_x) and nitrogen oxides (NO_x) in the troposphere.

Changes in Valued Environmental Components: Acidity of atmosphere. Through dry and wet deposition, acidity of soil and freshwater (lakes and streams).

Exposure: Inhalation of SOx and NOx by humans. Ecosystems exposed to lower Ph.

Consequences: Fish kills and loss of aquatic life in acidified lakes. Forest dieback (from combined problems of acidification and elevated ozone). Possible human health effects include reduced lung function and possible water contamination. Premature mortality for sufferers of cardiac and respiratory problems. Materials damage including degradation of iron, steel, zinc, paint and stone.

15. Photochemical oxidant formation (smog, elevated ozone in the troposphere)

Human Activities: Fossil fuel combustion, biomass burning, industrial processes including use of organic solvents, surface coatings, chemical manufacture and petroleum refining..

Changes in material fluxes: Increased nitrogen oxides (NO_x) from fossil fuel combustion. Increased volatile organic compounds (VOCs, also called reactive hydorocarbons) from solvents and gasolines, highway vehicles, surface coating, organic solvents, solid waste disposal, chemical manufacturing and petroleum refining.

Changes in Valued Environmental Components: Photochemical oxidant formation. I.e. increased ozone. This is formed through the reaction of VOCs and NOx in the presence of sunlight.

Exposure: For human health, through inhalation.

Consequences: Damage to crops. Eye irritation. Decreased lung function including coughing, shortness of breath, possibly long-term lung damage such as premature aging of lungs. Degradation of works of art. Forest dieback (in conjunction with acidification).

16. Concentration of toxins (Hazardous and toxic air pollutants)

Human Activities: The full spectrum of industrial activities involved with the manufacture, use and disposal of chemicals, including: petroleum handling, drycleaners, solvent usage, pesticide application, waste disposal sites, waste incineration, metallurgical industries, chemical production and manufacture. Combustion of fossil fuels. Motor vehicles. Municipal sewage disposal, wastewater treatment.

Changes in material fluxes: Level of toxic chemicals in the atmosphere. There are hundreds of different toxic chemicals released to the atmosphere.

Changes in Valued Environmental Components: Toxicity of air.

Exposure: Inhalation.

Consequences: Increased human morbidity and mortality, including both cancer and non-cancer health effects. Ecosystem effects.

THE HUMAN ENVIRONMENT

17. Indoor Air Quality - Radon

Human Activities: Naturally occurring radiation which enters surrounding air and/or water in human structures. The nature of some structures and ventilation systems allows for accumulation radon.

Changes in material fluxes: Uranium-238 and radium-226 are present in most soils and rocks in widely varied concentrations. Radon gas forms from the decay of radium-226 (the fifth daughter of uranium-238).

Changes in Valued Environmental Components: Increased radiation level in human habitats.

Exposure: Inhalation.

Consequences: Lung cancer.

18. Indoor Air Quality - non-radioactive pollutants

Human Activities: Combustion of fuels inside buildings. Use of chemicals in buildings including cleaning solutions, pesticides, office supplies. Materials used to construct buildings. Level of ventilation in buildings is key factor in determining levels of indoor air pollutants.

Changes in material fluxes: Increased levels of nitrogen oxides from combustion of natural gas. Increased levels of chemical contaminants.

Changes in Valued Environmental Components: Quality of air inside buildings.
Exposure: Inhalation.

Consequences: Increased morbidity and mortality.

19. Exposure to Chemicals (including biological pathogens) in the workplace

Human Activities: Use of chemicals in the workplace.

Changes in material fluxes: Increased levels of chemical contaminants in work environment. There are over 30,000 chemicals in the U.S. alone which contribute to this problem.

Changes in Valued Environmental Components: The safety of the occupational environment is reduced.

Exposure: Inhalation, ingestion, absorption through the skin.

Consequences: Human mortality and morbidity.

20. Exposure to radiation (other than radon).

Human Activities: Medical exposure. Working and recreating in the sun, operation of nuclear power plants, constructing nuclear weapons, disposing of nuclear waste.

Changes in material fluxes: Medical X-rays. Radioactive particles carried downwind from nuclear power plants and weapons plants, radioactive water leaks within the nuclear power plants and weapons plants, radioactive particles seeping into land and water from nuclear waste sites.

Changes in Valued Environmental Components: Increased radiation in land, water and air.
Exposure: Inhalation, ingestion through food supplies and water, absorption through the skin.

Consequences: Human mortality and morbidity. Damage to ecosystems.

21. Accidental Chemical Releases

Human Activities: Use, storage, and transport of chemicals.

Changes in material fluxes: Release of toxic chemicals to the environment. This usually entails a high concentration release over a short period of time.

Changes in Valued Environmental Components: Toxicity of atmosphere, land and/or water.

Exposure: Humans and ecosystems exposed to chemicals.

Consequences: Human mortality and morbidity. Ecosystem damage. Commercial losses due to shut downs, clean ups and reduction in quality of resources.

RENEWABLE RESOURCE SUSTAINABILITY

22. Stock of fisheries

Human Activities: Fishing, other physical removal of fish.

Changes in material fluxes: Quantity of fish decreases.

Changes in Valued Environmental Components: Fish populations drop below levels of maximum sustainable yield.

Consequences: Loss of species, food supply, recreation. Hunger.

23. Stock of wildlife

Human Activities: Hunting, other physical removal of wildlife.

Changes in material fluxes: Quantity of wildlife decreases.

Changes in Valued Environmental Components: Wildlife populations drop below levels of maximum sustainable yield.

Consequences: Loss of species, food supply, recreation. Hunger.

24. Forestry reserves

Human Activities: Agroforestry, firewood cutting, burning of forests for conversion to of land to agricultural uses, forest fire.

Changes in material fluxes: Quantity of forests decreases.

Changes in Valued Environmental Components: Forest productivity drops below maximum sustainable harvest.

Exposure: Land and humans exposed to decreased forests.

Consequences: Loss of lumber, firewood, recreation.

25. Groundwater resources

Human Activities: Irrigation, drinking water extraction, industrial use.

Changes in material fluxes: Groundwater level drops.

Changes in Valued Environmental Components: Decreased supplies of groundwater. (Groundwater is extracted at rates greater than regeneration.)

Consequences: Losses to agriculture, industry. Significant welfare effects.

NATURAL ENVIRONMENTAL HAZARDS

26. Floods

Human Activities: Although caused by natural fluctuations in weather patterns, and seasonal weather patterns which bring monsoons, hurricanes, and other storm systems, human activities which alter the flow of water can contribute to flooding (or ameliorate it). The activities of importance include building dams and levees, wetlands conversion, modifications of coastline and coastal areas, irrigation, and settlement patterns.

Changes in material fluxes: Increase in water in rivers and lakes. Change in physical environment along shorelines.

Changes in Valued Environmental Components: Increased or decreased flooding.

Exposure: Contact with the force of fast moving waters. Submersion. Drowning. Ingestion of contaminated food and water.

Consequences: Contamination of food and water supplies. Human morbidity increases due to ingestion of contaminated food and water. Human mortality increases due to increases morbidity and drowning. Welfare losses from damage to crops, food and water supplies, and physical infrastructure.

27. Droughts

Human Activities: Although caused by natural fluctuations in weather patterns, the human activity of deforestation can contribute to changes in the average level of rainfall (i.e. can affect local climates).

Changes in material fluxes: Decreased rainfall.

Changes in Valued Environmental Components: Drought. Decreased water in lakes, rivers and reservoirs, decreased moisture in soil.

Exposure: Dehydration.

Consequences: Loss of crops and livestock populations. Hunger and thirst leading to increased human morbidity and mortality. Loss of electrical generation.

28. Pest epidemics

Human Activities: Due to changes in natural environment, or an environment that is always hospitable to large pest population. Can be influenced by use of pesticides and other agricultural practices such as monocultures.

Changes in material fluxes: In case of influence by use of pesticides, pests become resistant to pesticides. Monocultures can provide abnormally large amounts of food for a limited set of pests.

Changes in Valued Environmental Components: Growth of pest population, pest epidemic.

Exposure: Insect bites for humans and animals. Insects ingest or otherwise destroy crops.

Consequences: Loss of crops. Increased human mortality and morbidity from pest carried disease or hunger due to loss of crops.

Reference Codes for Scoring Worksheets

SOIE--The State of India's Environment (either '82 or '84)

SOTE--State of the Environment: A View Toward the Nineties

FAO-- FAO Yearbook 1988

Pest Res--Pesticide Resistance, Strategies and Tactics for Management

Stat Year Asia/Pac--Statistical Yearbook for Asia and the Pacific

UNEP--UNEP Environmental Data Reports

UB--Unfinished Business

MAB--Man and Biosphere, "Draft Environmental Report on India"

SOTW--State of the World

WRI--World Resources Institute

APPENDIX B

TABLE OF CONTENTS

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 1. Freshwater -- Biological

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
Biological contaminant levels high for long distances downstream from major cities (SOIE82). [See US case]

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Faecal coliforms above Indian safety levels at more than half of tested sights, and above UK and US levels at all sites; at approx. 1/3 sites, levels are more than 1000 times natural backgrounds. (UNEP87, pp.46-7; UNEP90, p.118; SOIE82, pp.20-2).

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Over periods in the early 80's, most sites have experienced increases in faecal coliform levels, with only one tested sight experiencing decrease. Average increase is 32% (UNEP90).

7. Population at risk 1 3 5 7 9

NOTES:
Approx. 45% of the populace does not have access to safe

drinking water; over 90% does not have access to sanitation facilities (SOIE82; WRI90).

8. Land area at risk 1 3 5 7 9

NOTES:
Most rural areas do not have access to safe water; less than 10% of urban areas have full sanitation facilities; 70% of surface waters polluted (SOIE82; WRI90).

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
[US case]

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
1.5 million children die from diarrhoea annually, 6000 cholera cases (SOIE82, p.129; WRI87, p.255). Score 7: .76-7.6 million.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
7 million cases of Guinea Worm infestation; extensive diarrhoea and cholera (SOIE82, p.129).

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
[See US case]

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No data available. Losses from recreation assumed lower than in US, but losses in water supply quality assumed higher. Estimate same order of magnitude.

14. Transgenerational 3 6 9

NOTES:
Biological contaminants are not long lasting.

15. Transnational 3 6 9

NOTES:
India responsible for its own biological pollution.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
Little improvement seen, extensive deterioration. No discernible trends of improvement. Assume continued mortality.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 2. Freshwater -- Metals and Toxins

1. Intentionality. 3 6 9

NOTES:
Pesticides are intended to kill pests.

2. Spatial Extent 1 3 5 7 9

NOTES:
India consumes large quantities of DDT and other long lasting pesticides; pesticides and other toxins travel long distances before breaking down (SOIE82).

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Many pesticides, industrial compounds, etc. have no natural background.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Heavy metals and toxic residues in sediments are highly persistent (SOIE82, pp.20-7).

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
No trend data in WRI, UNEP, etc. Note that iron production increases 2.2% annually, aluminum production up 3.4% annually (WRI89, p.312; WRI86, p.290). Assume this indicates some increases toxins in water.

7. Population at risk **1 3 5 7 9**

NOTES:
45% has access to safe water (WRI90).

8. Land area at risk **1 3 5 7 9**

NOTES:
70% of surface waters polluted; high concentrations of pollutants in urban areas (SOIE82, p.20).

9. Delay **1 2 3 4 5 6 7 8 9**

NOTES:
Some immediate poisoning expected, but much discussion focussed on bioaccumulation and potential chronic buildup of toxins (SOIE82). Assume main consequences are delayed.

10. Human mortality (current annual) **1 2 3 4 5 6 7 8 9**

NOTES:
500,000 cancer deaths annually, 167,000 from oral cancers (SOIE82, p.140). Of remaining 333,000, assume 20-30% due to water born toxins.

11. Human morbidity (current annual) **1 2 3 4 5 6 7 8 9**

NOTES:
Assume 50% mortality rates from all cancers; add effects of bioaccumulation of mercury, lead, pesticides, etc.

12. Natural ecosystem impacts (current annual) **3 6 9**

NOTES:
Extensive fish kills, with entire regions of rivers becoming lifeless (SOIE82, p.20-27).

13. Welfare effects (current annual) **1 2 3 4 5 6 7 8 9**

NOTES:
Extensive damage from fish kills, losses in livestock that eat contaminated food, increased corrosiveness of water. No data on loss amounts, but assume one order of magnitude higher than US given lack of regulations and extensive pollution.

14. Transgenerational 3 6 9

NOTES:
High persistence of toxins guarantees long term effects.

15. Transnational 3 6 9

NOTES:
Primarily Indian industry.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
No trends in improvement indicated.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 3. Freshwater -- Nutrient Loadings

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
[See US case]

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Some natural background from soils. WHO recommends upper limit of 11.3 milligrams/liter, and all Indian samples are under that limit (WRI87, p.320). Assume some concentration above background levels.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Unclear what level of buildup, since no trend data available. Fertilizer use increasing at 11% annually 1975-84 (WRI89, p.274). Assume slow increase.

7. Population at risk 1 3 5 7 9

NOTES:
No expressed health problems. Per capita fertilizer use is

much lower than in US, where health problems are occurring at very low levels.

8. Land area at risk 1 3 5 7 9

NOTES:
Estimate based on lower levels of fertilizer use.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No health effects reported for India (SOTW87, p.142).

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Significant ecosystem effects.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No evidence of losses; assume some productivity losses to freshwater fisheries.

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. **Commitment to Future Human Health Consequences.** 1 3 5 7 9

NOTES:

17. **Commitment to Future Ecosystem Consequences.** 3 6 9

NOTES:

18. **Magnitude of Future Consequences.** 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 4. Freshwater -- Sedimentation

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
Deforestation in Nepal contributes to sedimentation in India.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
No data on trends in sedimentation rates in India. Approx. 6 billion tons erode annually, 75 tons/hectare/year (WRI89, p.282). This rate is more than 4 times the US rate; assume one order of magnitude higher.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Siltation can effect hydroelectric projects in the distant future.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Erosion of cropland increases 5% annually.

7. Population at risk 1 3 5 7 9

NOTES:
No health effects.

8. Land area at risk 1 3 5 7 9

NOTES:
High rates of erosion occur on 27% of lands (WRI89, p.282). Estimate that this will affect a comparable percentage of waterways and the 1500 dams in India.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Fish yields affected by high levels of sedimentation (SOIE82).

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Declines in productivity of freshwater fishing.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Siltation cuts life of dams, hydroelectric projects by 33-50% (SOIE82, p.58-67). $430 million expenditure on irrigation and dams (StatYrbookAsiaPac, p.169). Assume losses of 5-25%.

14. Transgenerational 3 6 9

NOTES:
Decreased flood control ability due to dam siltation.

15. Transnational 3 6 9

NOTES:
Neighbors activities affect sediment levels.

16. Commitment to Future Human Health Consequences. **1 3 5 7 9**

NOTES:

17. Commitment to Future Ecosystem Consequences. **3 6 9**

NOTES:
Continued losses in freshwater fishing.

18. Magnitude of Future Consequences. **3 6 9**

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 5. Ocean Water Quality

1. Intentionality. 3 6 9

NOTES:
Includes pesticides.

2. Spatial Extent 1 3 5 7 9

NOTES:
Ocean currents transport pollutants over large distances (WRI87, p.126).

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Many pollutants have no natural background. Indian Ocean is the most oil-fouled in the world (WRI87, p.129).

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
DDT, radioactive pollutants are long lasting (SOIE82, p.22).

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
No data on trends. Pesticide use in India would score 7, offshore oil production (and accompanying spills) increasing at 28% annually and would score 9 (WRI89, p.327); assume ocean pollution in India will score 8.

7. Population at risk 1 3 5 7 9

NOTES:
3.3 million marine fishermen exposed to toxins; larger numbers exposed to contaminated seafood.

8. Land area at risk 1 3 5 7 9

NOTES:
Oil spills occur over 30-70% of coastal areas (WRI87, p.130).

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Toxins enter food chain quickly.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No data available. Assume one order of magnitude higher than US case given poorer controls and extensive pollution.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Extensive fish kills in estuaries.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Pollution affects marine fisheries; losses of $640 million annually (SOIE82).

14. Transgenerational 3 6 9

NOTES:
Toxins accumulate in marine wildlife, sediments. Plastics break down slowly.

15. Transnational 3 6 9

NOTES:
Primarily caused by India, though oil spills affect regional ocean quality.

16. **Commitment to Future Human Health Consequences.** 1 3 5 7 9

NOTES:
Carcinogens in marine animals.

17. **Commitment to Future Ecosystem Consequences.** 3 6 9

NOTES:

18. **Magnitude of Future Consequences.** 3 6 9

NOTES:
No trends of improvement indicated.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 6. Soil salinity, alkalinity, waterlogging

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: The salt and alkaline substances from one farmer's irrigation practices can wash into major river basins and affect water used by other farmer's further downstream

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Waterlogging--approx 3-4 times normal water table level in places, salinization and alkalinization are very difficult to figure out since the natural level of these substances varies considerably with the type of land. However, most of the land in India is probably not more than 10 times the normal saline or alkaline level (a small percentage of the land might be where the problem is very severe)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: In India, over 20% of the affected land will experience significant decreases in productivity for a long time. Over 7 million ha have already gone out of production (State of India Env 1982). At least 20% of the affected land would need some type of man-made intervention to recover--Indians have been getting some optimistic results by putting 2-15 tons of gypsum on a ha for several years (State of India Env 1982).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: 5.8% increase per year in the number of ha irrigated (Shah)--assume "business as usual" in constructing these works since conservation measures have been a very small part of the Five Year Plan. Guess that 50% of the newly irrigated land will have at least one of the problems discussed here=2.9%

7. Population at risk 1 3 5 7 9

NOTES: 7 million ha lost already
10 million ha will go out of production very near future
10 million ha "affected"= assume yield loss is 10%

17 million ha loses 100% yield = 17 million*1.5 tons foodgrain/ha
10 million ha loses 10% yield = 10 million*.10*1.5 tons food

TOTAL=27 million tons foodgrains lost (foodgrains account for 9/10 of what is sown on irrigated areas, normal yield on irrigated areas is 1.5 tons foodgrains/ha/yr (Sixth Year Plan)

dietary intake of Indians is 170,601 grams food/year/person (India in Persp)

27 million tones*1,000,000/170,601 grams = 158 million people

****NOTE--For all of the land problems, I am assuming that any food that is not produced in India and could have been (like the 27 million tones) would have gone to feed Indians and not been exported. The reason for this is that the foodgrain imports to domestic production for 1970 to 1982 were all positive (See Economic Social Survey of Asia 1982). The potential to feed everyone in India is present say agricultural scientists (State of India Env 1982).

8. Land area at risk 1 3 5 7 9

NOTES: Land area at risk is irrigated land--40 million ha irrigated in India, 20 million affected by salinity, alkalinity and waterlogging

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Time period for a growing season plus shipping to consumers

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Average number of deaths from protein-calorie malnutrition = 2119/year (Stat Year Asia/Pac). This is probably a gross underestimation but all of the other diseases listed by death, a causal link to lack of food was too large of an assumption. ***NOTE--the 2119 deaths will be attributed to lack of food. This lack of food will be attributed to the 3 land problems in this model (1. salinity, alkalinity, waterlogging=15% of the deaths 2. soil productivity=80% of the deaths 3. urbanization=5% of the deaths). The percentages are my own informed estimates.
2119*.15=318 deaths from this problem

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 30% of the population is malnourished (Sixth Year Plan), .30*762,507,000=228,752,100 malnourished each year

228,752,100*.15=34,312,815 malnourished due to salinity, alkalinity, waterlogging problems that prevent enough food from being produced for livestock and humans

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 27 million tons of foodgrain lost/year

assume 1/2 of the food lost is rice
assume 1/2 of the food lost is wheat

13,500,000 tons of rice*$302/ton = $4.07 billion (price FAO)
13,500,000 tons of wheat*$146/ton = $1.97 billion (FAO price)
TOTAl = $6.04 billion/year that has to be imported to feed people
GNP = approx $222,039,300,000 (World Econ Data 1989)

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: If Indian farmers could immediately begin irrigating in such a manner so that salinity, alkalinity, and waterlogging didn't occur or if they stopped irrigating--the problem already created by irrigation systems to the land would be severe enough so that it will take a long time (if ever) for the yield to be normal

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 7. Soil productivity, desertification

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Average size of Indian farm--own estimate

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Erosion--8000 million tons/year, 150 million ha affected (State of India Env 1982), 55 tons/ha/year, safe=6 tons/ha (Soil Conservation Service in U.S. says 5 tons/acre so converted to ha), 9 times over max sus yield

Deforestation-- 1 million ha/year unofficially (State of India Env 1982), approx 132,000 ha/year max sus yield (Repetto), 7.5 times

Grazing--10 times the sus yield of 1 ha/cow/year (State of India Env 1982)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Many of the forests will never regenerate as well since different types of younger trees are being planted, it can take 500 to 1000 years to form 1 cm of topsoil (State of Ind Env 1982)

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: Grazing--up 3%/year (Env Mgt in India), deforestation--.3% per year, erosion--up 5% per year

7. Population at risk 1 3 5 7 9

NOTES: of the cultivated area of 140 million ha, 75% seriously hit by erosion --.75*140 million = 105 million ha affected
Normal yield should be 2 tons/ha (Sixth Year Plan), assume as an estimate that yield is reduced by 25% on the 105 million ha. 52.5 million tons of food lost to feed Indian people each year
52.5 million tons*1,000,000 grams/(170,661 grams

consumed/person/year(India in Persp)) =307,627,401 people

8. Land area at risk 1 3 5 7 9

NOTES: 75% of cultivated land

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 2119/year die from malnutrition (Stat Year Asia/Pacific), assumed that the soil productivity problem (1 of 3 land problems in this model) accounted for 80% of the deaths
.80*2119=1696 people /year

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 30% of the population malnourished (Sixth Five Year Plan),
.30*762,507,000 = 228,752,100 228,752,100*.80 = 183,001,680

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 60,000 ha of irrigation potential is lost each year (the storage capacity in the dams is reduced by the siltation which washes into them) (State of India Env 1984-85)

52.5 million tons of foodgrains lost (from #7)

TOTAL = 60,000 ha*1.5 million tons/ha + 52.5 million tons of foodgrains = 52,590,000 tons foodgrains lost

assume 1/2 is rice, 1/2 wheat

(52,590,000/2)*$302/ton = $7.9 billion (price from FAO)
(52,590/2)*$146/ton = $3.8 billion (price from FAO)
TOTAL = 11.7 billion

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Even if the activities stopped today, their lasting effects will cause trouble for future generations

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 8. Quantity of arable land

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Average size of Indian city--own estimate

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: What would the maximum sustainable yield be? Assume Indians can build more cities without hurting the amount of good farmland

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Cities remain a long time

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Assume building cities is on-going

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: 1960--18% urban population
1980--25.5% urban population (Sixth Year Plan)

7. Population at risk 1 3 5 7 9

NOTES: 56,250,000 moved or were born into urban lifestyle rather than rural between 1960 and 1980 (Sixth Year Plan)

assume each person used .01 ha for habitation (usually .06 ha for habitation (Man & Biosphere) in the whole country so reduced it for the city)
56,250,000*.01= 562,500 ha used up in urbanization
each person requires .4 ha for food (Man & Biosphere)
562,500/.4 = 1406250 people affected by the lost food output

8. Land area at risk 1 3 5 7 9

NOTES: Land resource is 143 million ha for cropland, 562,500 removed for urbanization, assume 1/3 would have been cropland (a U.S. estimate for cropland removed by urbanization (Crosson))
562,500/3 = 187,500 ha

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Time period during which crop would usually be planted, harvested and shipped to consumers

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 2119 people/year die from malnutrition (Stat Year for Asia and the Pacific), this land problem in the KSG model contributes to 5% of the problem (salinity, alkalinity, waterlogging = 15%, soil productivity = 80%)
2119*.05 = 106 people per year

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 30% of the population malnourished (Sixth Five Year Plan), .30*.05*762,507,000 = 11,437,605

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 562,500 ha of land lost to urbanization in 1960-1980, 562,500*1.5 tons of foodgrains/ha (Sixth Year Plan) = 843,750 tons of foodgrains lost
assume 50% rice
assume 50% wheat
(421,875 tons*$302/ton)/20 years = $6.3 million
(421,875 tons*$146/tonne)/20 years = $3.1 million
(prices from FAO)

TOTAL = $9.4 million

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to 1 3 5 7 9
Future Human Health
Consequences

NOTES: The cities are taking away land for food--a judgement since

India may become self-sufficient in food production in the future which would mean no one would go hungry and it would score a "1"

17. Commitment to Future Ecosystem Consequences — 3 6 9

NOTES:

18. Magnitude of Future Consequences — 3 6 9

NOTES:

References

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U.S. Man and the Bioshphere Program & Secretariat of State, "Draft Environmental Report on India" prepared by the Science and Technology Division of Library of Congress.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: INDIA

ENVIRONMENTAL PROBLEM: 9. QUANTITY OF ANIMAL HABITAT

1. Intentionality 3 6 9

NOTES:

Intent to harm trees, plant life in deforestation and wetland conversion. Harm to animals is unintended but unavoidab`.e consequence.

2. Spatial Extent 1 3 5 7 9

NOTES:

Dams affect environment for long distances, with fishing harvests up to 150 km. away (SOIE85, p.103); wetland draining can affect large areas.

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES:

In India, 279 parks and reserves totalling 13 million hectares (32.1 m acres), all of which are over 1000 ha in size, are considered by the IUCN to be protected areas for nature conservation. (UNEP90, p.237, 296-99) This amounts to approx. 4.3% of the country that is well protected. At least 5 reserves protecting over 1000 sq km are found in each of the IUCN biogeographical zones found in India (WRI86, pp. 95-97). Thus, it seems that the status quo is within safe levels. (Also, an expert committee of the Indian Board of Wildlife has recommended that at least 4% (131,000 sq km) of the total land area be protected as nature reserves (SOIE85, p.319)) Protected reserves are growing at an average rate of rate of 0.5 m ha/yr (WRI86, p.283; WRI89, p.295; UNEP90, p.297). Also, note that total habitat remaining in India is approx. 615,000 sq km (WRI89, p.94)

Of habitat that is not protected well, wetlands and closed forests may be the most important. These have been declining in area at the rate of 0.77-0.8% annually in the northern 60% of the country (best avail. data; p. 249 UNEP90). Assume national average of 0.8% loss -- 300 sq km wetlands and 1400 sq km closed forests = 1700 sq km -- in habitat per year. 1700/615,000 = 0.27% loss annually.

Additions to habitat are probably minimal. Agricultural and population pressures are high; though arable lands have stabilized at around 25% of total, built up lands are growing at 1400 sq km/yr (UNEP90, p.249). In sum, assume losses of .27%/yr.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES:
Wetlands may be irretrievable; reforestation takes up to a hundred years (Scientific American, p. 112).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing activity.

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES:
Wetland conversion rate and deforestation of closed forests has been relatively constant over the period from 1950-1980 at about 0.7-0.8% annually. Preserves being added, some reforestation. Data for all habitat lands unavailable. Therefore, use wetland and closed forest conversion rates for change of habitat. (UNEP90, p.249)

7. Population at risk 1 3 5 7 9

NOTES:
Animals are directly at risk, people are not.

8. Land area at risk 1 3 5 7 9

NOTES:
All of India was once animal habitat and now only 20% is (WRI89, p.94). Does this mean that 80% is affected? Or do we want to use the % of existing habitat that is threatened? For now, assume the latter is to be used. Use % protected preserves over total habitat: 4.3%/20% = 21.5% not at risk; 78.5% at risk.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Lowest score unless subsistence hunters experience starvation; no indications found that this occurs, but more research needed.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Unclear. See 10 above.

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:
Species extinction.

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES:
Welfare losses assumed not to result from habitat loss per se, but from decline in stock of wildlife (problem 23).

14. Transgenerational 3 6 9

NOTES:
Species extinction.

15. Transnational 3 6 9

NOTES:
India is itself primarily responsible for habitat loss, although some regional affects may occur. More research needed.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:
Losses in potential medical advances are expected if species extinction continues. Assume middle levels of harm?

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:
Ongoing depletion of animal habitat implies continued extinction.

18. Magnitude of Future Consequences 3 6 9

NOTES:
Increased probability of extinctions.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 10. Pure Food

1. Intentionality. 3 6 9

NOTES:
Pesticides are intended to harm pests.

2. Spatial Extent 1 3 5 7 9

NOTES:
DDT, widely used in India, breaks down slowly. Therefore, a single release can be expected to affect a large area.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
No natural background for most pesticides, other pollutants. Safe levels exceeded by many compounds. 70% of pesticides used in India are banned or restricted in Western countries because they are excessively hazardous: DDT, BHC, Methyl parathion, Heptachlor, etc. are widely restricted and banned, but used in abundance in India.(SOIE85, p.201)

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
DDT, etc. last long periods.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Continual application of pesticides; improper disposal and accidental releases of other compounds.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
No data available on trends in levels of toxins in foods. However, pesticides in use are substantially more hazardous than those used in other countries, and use is expected to increase by 20% over 1984-5 to 1989-90, 3.7% annual increase. However, use of

some of the more hazardous compounds is declining (DDT and Lindane are both down), suggesting that compounds being released may be less harmful. Score 7: higher than US, but lower than simple increase in rate of pesticide use.

7. Population at risk 1 3 5 7 9

NOTES:
High usage of hazardous pesticides suggests highest score. Moreover, studies indicate that 50% of tested food samples contain pesticide residues, with 30% above safe levels. Human milk contaminated in 100% of samples in Punjab. (SOIE85, p.201)

8. Land area at risk 1 3 5 7 9

NOTES:
Resources is pure food. Highest score, for reasons given above in 7.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Up to 170,000 cases of poisoning annually, including village-wide incidents of poisonings by contaminated foods (SOIE82, p.141)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
See 11. below. Assume same order of magnitude as in USA, but high end of range.

11. Human morbidity **(current annual)** 1 2 3 4 5 6 7 8 9

NOTES:
No data on morbidity rates in India, but rough est. obtained by comparison with USA. Contaminants in human milk range from 3 times higher in Indians for DDE, to 12X for DDT, to 95X for HCH Lindane (UNEP87, p.100). Levels of lead in blood are almost twice as high for Indians (UNEP87, p.103). Up to 170,000 cases of poisoning annually in India (see 9. above), compared to 6000 in the USA (Costa, p.17) -- approx. 10 times higher per capita.

Estimate that morbidity rates are one order of magnitude higher in India than in USA: score 7, 76,000-760,000 cases annually.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

No data. In USA, 0.35% of agricultural produce is lost annually to contamination. Assume same est. for India: India's agricultural output is $49 billion annually, .35% is $175 million. Score 6, 21-210 million, but note that actual score may be higher.

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 12. Ultraviolet energy absorption

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Since CFC's are not a natural substance there is no natural background

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: The 2 CFC's (CFC11 and CFC12) stay in the atmosphere for over 100 years (Miller & Mintzer)

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing releases

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Average concentration of ozone in the stratosphere has fallen by 2%. The magnitude of decline varies by latitude and season.

Latitude: 0-19 degrees N 1.6%
19-30 degrees N 3.1%

Average for India = 2.3% from 1969-1986 (WI)
.13% per year

7. Population at risk 1 3 5 7 9

NOTES: Everyone exposed to UV-B

8. Land area at risk 1 3 5 7 9

NOTES: Whole country

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Estimate of a 10 year period for cancer to appear (EPA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No causal link established yet

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: UV-B may affect some growing processes but cannot find much evidence

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: .3% decrease in yields of soybeans for every 1% increase in UV-B flux--assume all crops (EPA)
.69% decrease in agricultural yields
92 billion in agricultural earnings
634 million lost--probably an overestimation although none of the effects on plastics, and other material damages were counted

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: there will be cancer deaths even if ozone depletion ceased today

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

References

United States Environmental Protection Agency, Office of Policy Analysis, Office of Policy, Planning and Evaluation. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 13. Climate Change

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: All over the world

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: CO_2--1.5 times what it was in 1800 (Trabalka)
CH_4--twice what it was in 1800 (Darmstadter)
N_2O--about the same (Darmstadter)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: N_2O--100 to 150 years
CFC--110 years
(EPA)

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing releases

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Global CO_2 emissions increasing at a rate of 2%
(UNEP)

7. Population at risk 1 3 5 7 9

NOTES: All of India would probably be exposed

8. Land area at risk 1 3 5 7 9

NOTES: All land at risk

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: There are many different scenarios but looking at the one that keeps emissions rates steady this is what is predicted

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No causal link

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No causal link

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: none right now

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: None right now

14. Transgenerational 3 6 9

NOTES: The emissions going into the air today will have consequences in the future

15. Transnational 3 6 9

NOTES: All countries contribute who have emissions

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: India would probably not be sufficient in food production to adapt readily to food losses

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Ecosystems will probably be changed

18. Magnitude of Future Consequences 3 6 9

NOTES:

References

Trabalka, John R. 1985. Atmospheric Carbon Dioxide and the Global Carbon Cycle, DOE/ER-0239

Darmstadter, et all. Impacts of World Development on Selected Characteristics of the Environment.

United States Environmental Protection Agency, Office of Policy Analysis, Office of Policy, Planning and Evaluation. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: Acidification--Acid Rain

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: 100 to 300 km in moist tropical air (State of India Env)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Sulphur emissions are 1.10 million tons in India from man-made sources--natural in N.America is 3 million tons (NAPAP) so assumed Indian natural emission to be roughly the same (State of Ind Env)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: 1 week

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing releases

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Last 15 years--SO2 emissions have tripled
Last 4 years--NOx emissions have increased by 36%
(State of India Env)

7. Population at risk 1 3 5 7 9

NOTES: Trombay, Chembur, Delhi, Nagpur, Pune have reported acid rain--assume those populations at risk (State of India Env)

8. Land area at risk 1 3 5 7 9

NOTES: A circle of 100 km around each of the above cities assumed

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: The effects vary--research from U.S. and Sweden

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: ****NOTE--assume that the 18870 deaths/year in India from malignant neoplasm of trachea, bronchus and lung, pneumonia, and bronchitis, emphysema and asthma (Stat Year of Asia/Pac) are 50% due to indoor air pollution (nonradioactive in this model) and 50% due to the 2 atmosphere problems in this model (acidification (sulfates) and concentration of toxins)
18870/2 = 9435 due to atmosphere problems
9435/2 = 4718 due to acidification (sulfates in the air)

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: estimated an order higher on the scale

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: materials is probably the extent of the Indian problem since it is not as severe as in N.America and Europe where the forests and crops and fisheries are damaged

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES: No other countries contributing

16. Commitment to 1 3 5 7 9
Future Human Health
Consequences

NOTES:

17. Commitment to 3 6 9
Future Ecosystem
Consequences

NOTES:

18. Magnitude of Future Consequences   3   6   9

NOTES:

References

Centre for Science and Environment. 1984-85. The State of India's Environment: The Second Citizen's Report.

United Nations. 1988. Statistical Yearbook for Asia and the Pacific.

The National Acid Precipitation and Assessment Program (NAPAP). 1987. Interim Assessment: The Causes and Effects of Acidic Deposition, Vol 1, Executive Summary, U.S. Govt Printing Office, Washington, D.C.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 15. Photochemical oxidant formation (smog)

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Ozone from urban areas can travel several hundred miles into rural India (State of India Env)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: NOx emissions naturally in N.America are 5 millions of MT per year (NAPAP), assume natural emissions of NOx approximately the same in India-- man-made NOx emissions in India are not far above this

SO2 emissions are 1.1 million tons per year in India, natural background in N.America is 3 million tons per year (NAPAP) (assume it is the same in India) (State India Env)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: NOx-- 10 days (OTA)
VOC--days

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: NOx 9% per year in India, VOC? (State of India Env)

7. Population at risk 1 3 5 7 9

NOTES: urban population--25% (Sixth Year Plan)

8. Land area at risk 1 3 5 7 9

NOTES: % of air that is urban

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: several days--depends on weather (OTA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No evidence to link smog to deaths

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Respiratory symptoms are aggravated, an estimate

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: material damage and crops would be included--the problem does not seem bad enough in India to affect the crops severely. The estimate I am giving is one for material damage done to some of the buildings and archeological treasures. EPA estimated 10M to 100M in materials damage for the United States. Since Indian problem does not seem as bad as the U.S.--took the low estimate of 10M from EPA to use as India's materials damage which is probably too high.

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Might damage human lungs but no evidence for permanent damage

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Plants, etc can recover from smog effects

18. Magnitude of Future Consequences 3 6 9

NOTES:

References

Centre for Science and Environment. 1984-85. The State of India's Environment: The Second Citizen's Report.

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Government of India Planning Commission. 1980-85. The Sixth Five Year Plan.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 16. Concentration of Toxins

1. Intentionality 3 6 9

NOTES: Some come from pesticides

2. Spatial Extent 1 3 5 7 9

NOTES: Can travel long distances--several thousand kilometers (State of India Env)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Many of the pollutants not found in nature

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Carbontetrachloride 10 years, Lead 1-2 weeks, N2O 100 years are some examples

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Total suspended particle matter in Calcutta, Bombay, Delhi, Nagpur increasing at .75% per year (State of India Env 1982) This is not for all over India but only for the urban areas for which there were any statistics

7. Population at risk 1 3 5 7 9

NOTES: Major urban population--25% (Sixth Year Plan)

8. Land area at risk 1 3 5 7 9

NOTES: % of air that is urban

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: The carcinogens have a latency period of about 10 years for cancer effects (EPA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: this atmosphere pollution problem accounts for 1/2 of the outdoor air pollution deaths (SEE NOTE in ACID RAIN problem) 18870*1/2*1/2 = 4718 (Stat Year Asia/Pac)

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Estimated an order higher on the scale

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Material damage in the urban areas would account for the majority of the welfare effect since rural areas (therefore crops) do not seem to be affected badly yet.

14. Transgenerational 3 6 9

NOTES: Some of the pollutants can cause mutant genes

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

References

Centre for Science and Environment. 1984-85. The State of India's Environment: The Second Citizen's Report.

United States Environmental Protection Agency, Office of Policy Analysis, Office of Policy, Planning and Evaluation. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems.

Centre for Science and Environment. 1982. The State of India's Environment: A Citizen's Report.

Government of India Planning Commission. 1980-85. Sixth Five Year Plan.

United Nations. 1988. Statistical Yearbook for Asia and the Pacific.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 17. Indoor Air -- Radon

Note: No discussion of radon problems is found in sources used. Assumptions made are based on US case.

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
Releases are within homes.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Assume similar levels as US.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Radon has a half-life of 4 days. See US case.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

7. Population at risk 1 3 5 7 9

NOTES:
Approx. 500 million Indians live in rural villages. Assume that housing in these villages is not well insulated and that air exchange is good. Population at risk will be the remaining third of the population; urban homes assumed to be similar to US (SOIE82).

8. Land area at risk 1 3 5 7 9

NOTES:
Indoor air quality of approx. one third of housing.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Assume comparable number of deaths as US: 20,000 (WRI87, p.149); approx. 270 million urban dwellers in India and 250 million total US population. Score 5: 7600-76,000.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Assume 50% survival rate, as in US case.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Welfare effects do not include health related costs. Other costs (testing, increasing ventilation, etc.) not indicated.

14. Transgenerational 3 6 9

NOTES:
[See US case]

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
Assume Indian homes will become increasingly better insulated.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 18. Indoor air quality-nonradioactive pollutants

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Remains inside home

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: domestic pollution seems to be by far the most serious problem of indoor air pollution, emissions from wood burning and biomass fuels do not have natural backgrounds most of the time

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: The chemicals from the emissions (most in the factories of India) can remain for decades.

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: ongoing

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Only measurement available was that biomass fuel burning (nearly all of the biomass emissions are respirable) is increasing per year while charcoal burning is decreasing dramatically in the home (State of India Env 1984-85). Charcoal burning is much safer than biomass or wood burning in the home. Decided to give it the lowest "increasing" score on the scale.

7. Population at risk 1 3 5 7 9

NOTES: cooking and heating in the house usually affects everyone in the family

8. Land area at risk 1 3 5 7 9

NOTES: took resource at risk to be indoor air and assumed most of the indoor air (either in the workplace or the home) was affected

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Some of the emissions are carcinogens--10 year latency period for cancer to appear (EPA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Assumed this problem was 50% of the problem for deaths from malignant neoplasm of trachea, bronchus and lung, bronchitis, emphysema, asthma and pneumonia (Stat Year for Asia/Pac) = 18,870 *.5 = 9435

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: estimated an order higher on the scale

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Materials damage would constitute most of the welfare effects but in most Indian homes there are not a lot of material possessions although some material damage in the workplace. Probably an underestimation on my part.

14. Transgenerational 3 6 9

NOTES: Some of the pollutants in the workplace and at home can cause mutant genes

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES: Cancers are likely to appear in the future

References

United States Environmental Protection Agency, Office of Policy Analysis, Office of Policy, Planning and Evaluation. 1987. Unfinished Business: A Comparative Assessment of Environmental Problems.

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Centre for Science and Environment. 1984-85. The State of India's Environment: The Second Citizen's Report.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 19. Exposure to chemicals in the workplace

1. Intentionality 3 6 9

NOTES: Pesticides produced

2. Spatial Extent 1 3 5 7 9

NOTES: Within workplace

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Most chemicals not found in nature

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: A large majority of the chemicals last for decades

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Exposed daily

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: The only information was the use of chemicals in the workplace has increased drastically--scored this the lowest on the "increasing" part of the scale since some information did imply that workers are slowly getting better protective devices (State of India Env)

7. Population at risk 1 3 5 7 9

NOTES: Number of workers in the following professions--

mining/quarrying	1087
manufacturing	6183
agriculture	1305
elecricity/gas	799
construction	1216
transport/storage	2984

TOTAL (in thousands) 13574

(Stat Year Asia/Pacific--these numbers include public sector and establishments of nonagricultural private sector with 10 or more persons employed) TOTAL likely to be an underestimation because of the > 10 rule

8. Land area at risk 1 3 5 7 9

NOTES: Resource is the working environment--assumed almost all environments have some type of chemical to which the worker would be exposed

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Carcinogen materials have a period of about 10 years before cancer appears (EPA)

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 100 from the chemical industry, 500-700 from silicosis, asbestosis, byssinosis (State of Ind Env)--no other data on other illinesses so this is an underestimation but to make it go to the next scale score (a "5") approximately 765,000 workers would have to die each year

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: An order higher on the scale estimated since little data available

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Corrosion of materials would be the primary cost--estimate to be somewhat smaller than U.S. since not as many chemicals used in as many places as in the U.S.

14. Transgenerational 3 6 9

NOTES: many of the chemicals (carbontetrachloride for instance) can cause mutant genes (EPA & State of Ind Env)

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

References

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 20. Exposure to Radiation

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
Releases of radioactive materials can travel extensive distances.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
India has a small but growing nuclear power industry; 6 power plants were in operation in 1986 and 4 more were under construction (WRI89, p.311). Estimate concentration of radiation above natural background.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
The nuclear power program is growing by one plant every 5 years 1970-86, a rate of approx. 7% (WRI89, p.311). Given poor record in management of other toxic wastes, assume India will face increasing problems of exposure to radiation at a similar rate.

7. Population at risk 1 3 5 7 9

NOTES:
Radioactive wastes can be expected to be poorly handled. Other sources of exposure to radiation also affect Indians; for example, increased cancer rates throughout the northern hemisphere are predicted because of the Chernobyl accident (28,000 additional cancers over 50 years predicted in WRI89, p.124).

8. Land area at risk 1 3 5 7 9

NOTES:

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
[See US case]

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No data. India has 2.5% as many nuclear power plants as the US, where 220 deaths annually are estimated [See US case]; assume 2.5% as many deaths in a population three times larger, or approx. 17 deaths annually. Score 2: 7.6-76.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Based on 50% mortality rate [See US case].

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No data; estimate on same reasoning as 10 above.

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

For example, accident at Chernobyl will affect entire hemisphere.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 21. Accidental Chemical releases

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Some of the chemicals in major incidents traveled several hundred miles from the point of release (State of India Env & UNEP)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Many of the chemicals have no natural background level

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Several decades for two of the chemicals released (UNEP)

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: 5 "major chemical accidents" in India reported by UNEP from 1960 to 1987

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: 1960-1968--1
1969-1977--0
1978-1987--4
Not robust enough data to determine change??

7. Population at risk 1 3 5 7 9

NOTES: 300,000 people employed in the chemical industry in India (State of India Env 1985) (in U.S. EPA estimated that 95% of the people who are at risk from chemical accidents are chemical workers--will use this assumption for India also realizing that Bhopal struck many ordinary people which was an exceptionally bad accident)

8. Land area at risk 1 3 5 7 9

NOTES: assume transportation and placement of factories is in less than 30% of India

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Carcinogens present in the releases which occurred--10 year latency period for cancer (EPA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 2552 deaths from 1960-1987 is approx 95 deaths per year (UNEP)

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 50,116 over 27 years were injured (from UNEP)-- 1856/year
**Majority of the cases were from 1984 Bhopal where 50,000 were injured

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Ranked low since only 5 accidents and no species reported severely threatened by the accidental chemical releases

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: The costs involved in cleaning up the accidents. The U.S. had 7 times as many accidental chemical releases as India did during this same period. EPA estimated the welfare effects to be approximately $99 million/year. For a very rough estimation (no other sources of information were found) took 1/7 of the U.S. welfare effects=14 million/year.

14. Transgenerational 3 6 9

NOTES: Two of the leaks had chemicals which can cause mutant genes

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Mutant genes in humans

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 22. Stock of Fisheries

NOTE: Focus is on marine fishing only; freshwater fishing is significant (37% of 1984-6 harvests) but data is extremely limited. Overfishing and depletion of stock is not indicated in either freshwater or marine fishing.

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
Score 1; only countries that make substantial use of large purse seine nets (i.e., Japan) will score higher.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Assume marine fishing occurs primarily in Indian Ocean. Western Indian Ocean (WIO) is currently "underexploited" -- harvest could expand without detrimental effects (WRI89, p.148). Eastern Indian Ocean (EIO) has estimated sustainable yield at 1.5-2.2 million metric tons annually, with current harvest at 1.8 (WRI89, p.328). No indications of harvest above sustainable yield in EIO, below MSY in WIO. Score R<1.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Current harvests are not limiting productivity.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Although Indian marine harvests are increasing by approx. 0.03-0.04 million tons/yr (UNEP87, p.161-2; UNEP90, p.286-6), as is overall harvest from Indian Ocean (WRI89, p.328), changes in stock do not seem to be occurring since no depletion problems are found.

7. Population at risk 1 3 5 7 9

NOTES:
Some subsistence fishing, but no indication of problems.

8. Land area at risk 1 3 5 7 9

NOTES:
Resources are not currently exposed to overfishing.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
None.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
No significant declines in productivity.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No losses indicated.

14. Transgenerational 3 6 9

NOTES:
Present activities do not indicate future problems.

15. Transnational 3 6 9

NOTES:
Score 3 because no declines in productivity, even though fishing in Indian Ocean is undertaken by more nations than India.

16. **Commitment to Future Human Health Consequences.** 1 3 5 7 9

NOTES:

17. **Commitment to Future Ecosystem Consequences.** 3 6 9

NOTES:

18. **Magnitude of Future Consequences.** 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 23. Stock of Wildlife

1. Intentionality. 3 6 9

NOTES:
Intention to harm animals through hunting.

2. Spatial Extent 1 3 5 7 9

NOTES:
Local impact.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Data for determining maximum sustainable yield is unavailable; most species' MSY has not been determined. Therefore, use status as endangered species as proxy for harvesting above MSY. Depending on source, 0.17-6.4% of mammal and bird species are endangered. (WRI89, p. 297; SOIE82, p.168; MAB, p.iii) Several species, currently hunted for pelts, are on the verge of extinction (SOIE82, pp.167-68); assume <u>any</u> harvesting is too high.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Some species extinction, much endangerment.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Hunting is ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Data on hunting rates is limited; increased rate in species endangerment is sign of increased harvesting, but preservation projects (Project Tiger) is sign of better management. Assume slight increase in harvesting/species loss.

7. Population at risk 1 3 5 7 9

NOTES:
Subsistence hunters might be at risk, but primarily animals alone are at risk.

8. Land area at risk 1 3 5 7 9

NOTES:
Depending on data, 0.17-6.4% of species are endangered and at risk.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Subsistence hunters could experience mortality, but no data suggests that this occurs at present.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
See 10 above.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Extinction of species.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Limits to tourism, etc. Tourist trade is $820 million annually, some % of which is assumed related to wildlife. No data available, but data for Thailand indicates that 4 million visits/yr to parks and protected areas occur (UNEP87, p.276), out of 11 million visitor days to Thailand = 36%; assume similar rate of visitation in India. Finally, assume 5% loss due to loss of

wildlife (up to 6.4% endangerment). India has 37.5 million visitor days, 36% visits to parks and protected areas = 13.5 million visits yearly. Average tourist daily expenditure is $33: 13.5 million * $33 * 5% = $22 million potential losses. Given high uncertainty of estimates, especially visitation rates to parks, score 5: $2.1-21 million.

14. Transgenerational 3 6 9

NOTES:
Species extinction.

15. Transnational 3 6 9

NOTES:
Assume some activity by neighbors which affects migratory species.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
As species become extinct, genetic material is lost that could have yielded new medicines, etc.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:
Species extinction.

18. Magnitude of Future Consequences. 3 6 9

NOTES:
Species extinction.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 24. Forestry Reserves

1. Intentionality. 3 6 9

NOTES:
Harm to animals is picked up under #23 habitat loss.

2. Spatial Extent 1 3 5 7 9

NOTES:
Primarily local impact.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Increases in harvests of all forestry products (UNEP90, p.269 and p.175; WRI90, p.289). However, most sources suggest that forest cover is declining (UNEP90, p.249); deforestation rates are approx. 0.2% in India 1981-85 (WRI, p.73); 147k ha deforested/72521k ha closed forest (0.3% suggested in UNEP87, p.158). [Note: data concerning the amount of forest cover in India is conflicting; some sources suggest that the amount of "forest and woodland" is increasing (UNEP90, p.242), although woodland may refer to unproductive wooded areas.]
Assume 0.2-0.3% deforestation is level of overuse: score 3.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
High score given deforestation and deficits occurring in fuel wood consumption. Reforestation can take decades, and up to 100 years in badly damaged regions. (Scientific American, Sept. 89, p.112)

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:

Estimate that consumption of roundwood is increasing at constant rate of approx. 2.5% annually since 1972. (WRI86, p.277; WRI90, p.289) Est. 2.1% over 1977-86 (StatYrbookAsiaPac, p.148).

7. Population at risk 1 3 5 7 9

NOTES:

Approx. 91% of roundwood production in India is used for fuel wood -- 212.6 m cubic meters in 1983, up 23% since '73. Fuel wood deficits are occurring in several regions in India; rough estimates are that 250 million people face deficits in rapidly expanding agricultural regions, and another 287 million face deficits in densely populated lowlands. Total is approx. 540 m. consuming more than is replenished. [Est. based on India's pop. compared to total pops. for regional deficit values] (WRI86, p.70).

8. Land area at risk 1 3 5 7 9

NOTES:

Approx. 32 million ha are managed (WRI86, p.65) of total 67 m ha (StatYrbookAsiaPacific, p.146).

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

None.

11. Human morbidity **(current annual)** 1 2 3 4 5 6 7 8 9

NOTES:

None.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

Deforestation and overcutting will cut productivity.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Fuel wood prices up 6-10 times between 1960-83 due to scarcity (SOTW86, p.29). Approx. 5-6% of average household expenditures on fuel and heat (Statistical Sources and Methods, International Labor Office, Geneva, pp. 107-11). GNP per capita in 1987 was $300 (World Tables, World Bank). Assume 5% of 300 = 15$ on fuel, est. half is fuel wood, est. 6 times more expensive due to scarcity = $960 million.

14. Transgenerational 3 6 9

NOTES:
Better management trends not indicated yet; high prospects for continuing deficits in future.

15. Transnational 3 6 9

NOTES:
India causes its own problems.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:
Continued declines in productivity.

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 25. Groundwater Resources

1. Intentionality. 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:
Regional effects from excessive pumping.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Only 3% of available water in India is groundwater. Generally, groundwater depletion is not a problem, although certain regions are experiencing overdraft (SOIE82, p.17; Irrigation in India's Agricultural Development, B.D. Dhawan, ch.5).

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Recharging aquifers can take centuries.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
No trend data. Assume one order less than US case given low levels of use.

7. Population at risk 1 3 5 7 9

NOTES:

8. Land area at risk 1 3 5 7 9

NOTES:
Only a few regions are mentioned as having overdraft problems. Tamil Nadu, Chandigarh, Gujarat states mentioned (SOTW90, p.46; SOTW89, p.50; Environmental Management in India, K.P Singh, p.39).

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Little discussion of welfare effects, although "thousands of villages rely on trucked in water because of mining" of groundwater (SOTW89, p.50).

14. Transgenerational 3 6 9

NOTES:
In overdraft regions, long lasting effects.

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 26. Flooding

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Rising flood waters can affect land, people, buildings for hundreds of miles in a river basin and the contaminants from a flood can travel as far

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Judgement that flood waters would not be more than 100 times the normal water level

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Cropland can be damaged by losing topsoil that never returns, human structures can take decades to rebuild

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: From data in India 1973-1986 (UNEP)

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: The area subject to flooding increased by 320% from 1960 to 1984 (WWI)

7. Population at risk 1 3 5 7 9

NOTES: 1/3 of India's population lives in flood prone areas (El-Sabh)

8. Land area at risk 1 3 5 7 9

NOTES: 60 million ha at risk from flooding (WWI) / 328 million ha (total geographical area of India)

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: contamination in the food from rising waters can cause cancer--assume a 10 year period before cancer appears (EPA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: approx 2,000 people/year since 1973 (UNEP)

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Estimated an order higher on the scale than deaths

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 1,130,000 in U.S. dollars (ESSA)

14. Transgenerational 3 6 9

NOTES: Loss of productivity of farmland

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Activities engaged in today (dams, shoreline building, etc) -- even if they are stopped today--will encourage flooding in the future

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES: There is an increase in the activities which lead to flooding--more flooding so greater consequences

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 27. Drought

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Used average size of a drought region in India--718,854 km^2/11 drought prone states (India Symp)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: How many inches less than normal is a drought? Annual rainfall for India is 122 cms and the government classifies a region receiving less than 75 cms as a drought prone region (India Symp)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: more groundwater used than normal, some regions have been permanently damaged by drought for farming

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: substantial areas affected by droughts every 4 to 5 years (State of India Env)

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Data from several states in India shows and increase in the number of droughts over the last 185 years--the second half of this period had more droughts than the first half (India Symp)

7. Population at risk 1 3 5 7 9

NOTES: 35% of the total population (India Symp)

8. Land area at risk 1 3 5 7 9

NOTES: 47% of the land in India is at risk in the 3 zones of drought prone areas (extreme, severe, and moderate) (India Symp)

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: When planting time comes around (twice a year) the land may not have recovered so food will not reach consumers

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES:

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: An order higher than mortality estimated

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: The 1982/83 drought season decreased agricultural production by 4.9%, the 1986/87 decreased it by 4% (Asia Year and UNEP)

144 million tons of foodgrains produced in 1987 (Stat year)

.045*144 million tons = 6.48 million tons

6.48 million/2 * $302/ton rice = 978.4 million (price from FAO)

6.48 million/2 * $146/ton wheat = 473 million (price from FAO)

TOTAL = 1.45 billion

Perhaps an overestimation but the amount the Indian Government spent on relief measures is not included--did not want to double count in case the relief measures were to buy food

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences   3   6   9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: India

ENVIRONMENTAL PROBLEM: 28. Pest Epidemics

1. Intentionality. 3 6 9

NOTES:
Pesticides are intended to kill pests.

2. Spatial Extent 1 3 5 7 9

NOTES:
Changed material flux is emergence of newly resistant species; unclear how to treat "release" of increased resistance. Extent is local initially, but spreads through reproduction.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Between 1980-84, 4.4% increases in resistant pest species worldwide, for annual increase of 1.09%. Individual species may be resistant to several pesticides, with (new species) * (pesticides to which it is resistant) = 9.4% over same period, 2.3% annual average (Pesticide Resistance, National Research Council, p.18).

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Assume species resistance is essentially permanent.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Approx. 4.75 new resistant species worldwide per year, ave one every 2.5 months. Assume newly resistant pests spread globally.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
At 1.1% new species annually, doubling time is over 40 years. At 2.3% (new species * pesticides resistant) rate, doubling time is closer to 30 years. Use latter to focus on increased resistance, rather than species. (PestRes, p.18)

7. Population at risk 1 3 5 7 9

NOTES:

In India's case, population at risk would be number exposed to vector born disease such as malaria and filariasis. The population at risk from filariasis has risen from 25 million in 1963 to 236 million by 1976, with 15 million cases annually. Malaria initially diminished with intensive applications of DDT, dropping from 100 million cases in 1952 to 100,000 in 1965. By 1982, up to 2-2.5 million cases annually were occurring, with some number greater of at risk population; increases were brought about by mosquito resistance to pesticides. (SOIE82, p.133-38; WRI87, p.255). By 1984, anopheles mosquitos in India were largely resistant to DDT and other pesticides (PestRes, p.27).

Moreover, high numbers will be at risk from pest epidemics; desert locust epidemics cause crop losses periodically. (UNEP90, pp.231-33) Score 7: 30-70% at risk (230-536 million of 760 million).

8. Land area at risk 1 3 5 7 9

NOTES:

Agricultural lands are primarily exposed to changes in the VEC. India is 57% cropland and pasture, 23% woodland (UNEP90, p.244); some % of both is sprayed with pesticides and/or susceptible to pest epidemics. Assume score 7: 30-70% of land.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

Vector born disease mortality expected to be high in India, but no data for mortality exists in UNEP, WRI or WHO reports. Assume similar mortality rates in Africa, where 750,000 deaths from 6 million cases occur annually = 12.5% (UNEP90, p.348). 12.5% of 18 million is 2.25 million.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

See 10 above. 15 million cases of filariasis, 2.5 million cases of malaria, several thousand kala-azar and Japanese encephalitis (SOIE82). Approx. 18 million vector born cases annually, 2% populace.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Significant declines in agricultural productivity due to increased resistance and epidemics.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Assume 10% cost of pesticides is due to increased pest resistance (Pest Res, p.33). Assume 20% of agricultural expenditures on pesticides; 20% of $848 million = $170 million, 10% of which is $17 million (World Tables, World Bank, p.317).

14. Transgenerational 3 6 9

NOTES:
Assume species resistance is essentially permanent.

15. Transnational 3 6 9

NOTES:
Pesticide application by neighbors will affect pests in India.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
Current health effects are substantial; assume increased resistance and problems in future.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:

18. Magnitude of Future Consequences. 3 6 9

NOTES:

Reference Codes for Scoring Worksheets

SOIE--The State of India's Environment (either '82 or '84)

SOTE--State of the Environment: A View Toward the Nineties

FAO-- FAO Yearbook 1988

Pest Res--Pesticide Resistance, Strategies and Tactics for Management

Stat Year Asia/Pac--Statistical Yearbook for Asia and the Pacific

UNEP--UNEP Environmental Data Reports

UB--Unfinished Business

MAB--Man and Biosphere, "Draft Environmental Report on India"

SOTW--State of the World

WRI--World Resources Institute

APPENDIX C

TABLE OF CONTENTS

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Freshwater - Biological (Pathogenic microorganisms)

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Bacterial movement does not proceed far in groundwater (Waite, p. 154). In streams, if lasts for up to a month, with water velocity of 30 km/day -> still a sub-continental problem. Groundwater alone would score "1".

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Legionella: 10-100; Pathogens (Giardia/Viruses) 100-1000. (EPA UB). Fecal coliform and fecal streptococcus levels are likely to be higher. This finding verified by data in UNEP 1990 Environmental Data Report.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: In groundwater, lifetime of bacteria up to 60-100 days (Anderson). For freshwater, bacterial counts become high with input of sewage; in flowing stream, will decline in a period of days (Camp). Lifetime of bacteria in freshwater seems on the order of days to a month (Waite).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Many releases of sewage are continuous.

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Levels of bacteria in surface water improved notably in between 1974 and 1981. Fecal coliform, median annual improvement at 15 % of stations of 34.5%, degradation at 5% of 11.1%. Fecal streptococcus, improve at 23% stations, degrade at 3% (Cons. Found., 1987). 15% x 34.5% + 80% x 0 = 5.7%/yr. This data ends in 1980. Investment in wastewater treatment has been improving over the past 2 decades, so this seems reasonable.

7. Population at risk 1 3 5 7 9

NOTES: Legionella: 109,000-10,000,000. Pathogen > 10 x 10^6 (US EPA, UB). 10% of total groundwater supplies exceed standards for microbial contaminant (Cons. Found., 1987). 50% of US drinking water supplied by groundwater. Therefore, at least 5% of US population is exposed to unsafe levels of microbial contaminants.

8. Land area at risk 1 3 5 7 9

NOTES: In this case, interpret as percent of water supply which exceeds standards. Have data for groundwater of 10%.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Illness is experienced within hours to days. Thus, this would score the same as persistence, as the delay is the time from release to effects.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No mention of mortality from waterborne disease. It's fair to assume a very small number of deaths from the types of waterborne illnesses experienced in the US.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 34,337 cases in 12 years from groundwater. 86,048 for 12 years from surface and groundwater. These are reported cases only. They are an underestimate (Patrick). 4.365 from virus 1945-1985 (Patrick). Approx. 10,000 cases of water-born illness per year. Large proportion of these are from biological components. (Of 50% with known cause, 85% from biological).

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Bacteria do contribute to biological oxygen demand, and thus, to the problem of reducing levels of dissolved oxygen which are needed by fish and other aquatic life.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Some recreational effects. US EPA estimates that the cost in recreational values from municipal & industrial are 2.5B and 0.8B, respectively. This equals 3.3B total. Bacterial concentrations are only a portion of this, but from municipal they are probably a large portion.

14. Transgenerational 3 6 9

NOTES: Short-lived in environment, no problems which are passed to next generation.

15. Transnational 3 6 9

NOTES: Although there is a contribution to Great Lakes pollution by Canada, it is fair to say they are not a significant contributor to U.S. water problems. The Great Lakes have been improving in quality due to joint US-Canadian clean-up efforts.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

REFERENCES

Camp, Thomas R. and Robert L. Meserve, 1975. Water and Its Impurities 2nd ed. Dowden, hutchinson and Ross, Inc. Stroudsberg, PA.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Freshwater - Metal & Toxics

1. Intentionality 3 6 9

NOTES: Pesticides are a significant contribution to this problem.

2. Spatial Extent 1 3 5 7 9

NOTES: Toxic impacts are generally most severe in the immediate vicinity of discharge where concentrations are highest. Certain persistent toxicants may be transported a considerable distance before they are deposited & bioconcentrated in the food chain (EPA UB). Assume sub-continental, i.e. size of watershed. For groundwater, a common rate of movement is 10 - 100 meters/year. Groundwater plumes tend to be of smaller distance than the size of a watershed. Groundwater alone would score "3". (Conservation Foundation). For groundwater, contamination remains relatively localized over long periods and becomes less diluted than would be the case in surface water. (Pye et al. 1983)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: This includes pesticides and other synthetic organic compounds which are not naturally present in the environment.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Sediment contaminants are likely to be non-volatile, persistent & hydrophobic. "The persistence of contaminated sediments is difficult to predict; time frames are likely to be measured in years, decades, or possibly centuries." (US EPA, UB) All of heavy-metal ions & some synthetic organic chemicals will not degrade in groundwater (Anderson).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Many of the discharges are continuous.

6. Rate of Change in material flux — 1 2 3 4 5 6 7 8 9

NOTES: Dramatic decrease in lead. 23% of stations report improvement, 2% degradation. Arsenic generally increasing, as is cadmium. Few trends for other metals. Industrial discharges of conventional pollutants declined by 70% from 1972-1977. No current data. Score of "5" as no discernible aggregate trend.

7. Population at risk — 1 3 5 7 9

NOTES: For list of 23 pollutants with cancer risks, including VOCs, synthetic organics (pesticides), & radionuclides. Pop. exposed > 100 million. Lead 1.7×10^7 (US EPA, UB). Between 1978 & 1981, 100s of wells affecting millions of people were closed due to contamination by toxic organic chemicals. 5-25% of rural wells had unsafe levels of metals. 20% of nation's groundwater supplies have at least one VOC present at detestable levels. 100,000-200,000 have consumed wellwater contaminated with pesticides (Cons. Found.)

8. Land area at risk — 1 3 5 7 9

NOTES: Interpret as water resource at risk. 73% of river miles, 78% of lake acres support designated uses (Cons. Found., from US EPA, 1984). 16% of nation's river reaches, 26% of river miles receive at least 1 discharge (EPA, UB). 57% of reaches receiving point discharges exceed one or more toxic criteria at low flow (US EPA, UB). Toxic contamination of fish in 10% of all waters (Cons. Found., 1984).

9. Delay — 1 2 3 4 5 6 7 8 9

NOTES: While some effects are acute, these substances can also cause chronic effects, with delays of decades (i.e., cancer).

10. Human mortality (current annual) — 1 2 3 4 5 6 7 8 9

NOTES: See cancer case estimates under #10. Total cancer cases 4,000-11,400. 50% of all cancer cases result in death.

11. Human morbidity (current annual) — 1 2 3 4 5 6 7 8 9

NOTES: Cancer cases from groundwater (per year):
Hazardous wastes, inactive: 3244 surface water max., 1114 best

est. Hazardous wastes, some active: 0.3-384, 30-40 conservative waste 112 per year.
Increased cancer cases through groundwater.
Note: hazardous waste sites active & non-hazardous waste sites given same rank as hazardous waste sites inactive. Assume similar level of morbidity Surface waters: 467-1160 (US EPA, UB).
Total, 4,000 to 11,400.

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES: Overall productivity reduced. Shifts in community structure. Species extinction is a great concern from sludge deposited in streams, wetlands, estuaries. (US EPA, UB).

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: EPA UB:
Corrosive water, as arrives at tap: 100M-1,000M.
Recreational values: [illegible].7B (pesticides, acid mine drainage, fertilizers) i.e., non-point. 2.5B (municipal, i.e., indirect point). 0.8B (industrial, direct point).
$100M-$1B crops (non-point sources) + 3 x $1-$10M for waste sites & groundwater contaminants.
$10M-100M damage to agric. land + $1-10M for waste sites.
$1M-100M fisheries (direct pt.)
$1M-100M fisheries (indirect pt.)
Hazardous waste sites, damage to groundwater supplies: 3 x $100M-$1000M
Pesticide damages to gw supplies: $1M-100M
Loss in property value from gw supplies: $1-10M
Up to $9B total damages. Large portion, but not all of this is from toxics.

14. Transgenerational 3 6 9

NOTES: Because of persistence.

15. Transnational 3 6 9

NOTES: With the exception of the Great Lakes, this is a domestic problem.

16. Commitment to Future Human Health Consequences   1 3 5 7 9

NOTES: Cancer is one of the effects. Some substances may be genotoxics, although I have not come across any specific evidence of this.

17. Commitment to Future Ecosystem Consequences   3 6 9

NOTES: Today's releases are persistent and will cause significant problems in the future. Species extinction is a concern.

18. Magnitude of Future Consequences   3 6 9

NOTES: Due to slow movement into groundwater, and increased amounts of toxic waste over the last two decades, expect future consequences to be worse than current consequences.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Freshwater - Eutrophication (Nutrient Loadings)

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: "Because natural biochemical oxidation of organic nutrients is a relatively slow process, the various impacts of pollution are typically expressed at considerable distance from the point of discharge." (EPA, UB). Spatial extent is the size of a watershed.

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Nitrates: score "1" in EPA UB with 1-10.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Lakes tend to trap nutrient phosphorous. The capacity of nutrients between sediments and overlying waters will tend to support algal growth for many years (EPA, UB). "In many situations, bottom sediments contain enough phosphorous to accelerate eutrophication ever after external sources have been terminated" (Waite, 1984). The experience of Lake Washington, back to swimmability in 6 yrs. although nutrients were still 20-30% above levels measured in 1950. Phosphorous is trapped in sediments. It will only be released under a condition in which the lake is depleted of oxygen. Thus, if releases of nutrients stop & the lake stops eutrophic cycle, phosphorous in sediments will stay put.

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Releases are continuous.

6. Rate of Change in material flux — 1 2 3 4 5 6 7 8 9

NOTES: Between 1972 and 1982, waste loads decreased 46% from municipal sources, 71% from industries (Cons. Found., 1987). From USGS survey (cited in Cons. Found.): Nitrates - 30% of stations cite annual degradation of 6.7%, 7% cite annual improvement of 8.7%. For phosphorous, 13% improve at 8.1%, 10% degrade at 7.4%. Regional differences.
-(30 x 6.7%) + (7% x 8.7%) = -1.4%
(13% x 8.1%)-(10% x 7.4%) = .31%
Conclusion: Point sources decreasing, non-point sources increasing. More data may confirm my suspicion of a score of "6".

7. Population at risk — 1 3 5 7 9

NOTES: For Nitrates. 1.5×10^4 (US EPA, UB).

8. Land area at risk — 1 3 5 7 9

NOTES: Non-point sources are responsible for 82% nitrogen and 84% phosphorous. 29% of lakes and rivers affected by non-point sources (Cons. Found.). This is scored as "water resource" at risk.

9. Delay — 1 2 3 4 5 6 7 8 9

NOTES: Eutrophication requires photosynthesis. Health effects require ingestion of nitrates.

10. Human mortality (current annual) — 1 2 3 4 5 6 7 8 9

NOTES: Nitrates converted to nitrites. Cause methemoglobinia. Infants particularly susceptible. One incident of death has been reported in US since 1960 (Patrick, et al.). Could be underreported.

11. Human morbidity (current annual) — 1 2 3 4 5 6 7 8 9

NOTES: 4 acute cases of methemoglobin reported in recent years. There is a chronic health hazard associated with nitrites. They interact with amines or amides to form compounds which produce cancer in laboratory animals. But, nitrate would have to be bacterially converted to nitrite first. No estimates of health risk (Patrick).

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES: Changes community structure from "clean water species" to ones dominated by "pollution tolerant" forms. In extreme case, can be lethal to higher aquatic organisms.

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: These are input from domestic, industrial and agricultural waste.
EPA UB estimates loss in recreational values from all sources at \$7B plus damage to fisheries at \$1M-100M. A significant fraction of this could be from eutrophication.

14. Transgenerational 3 6 9

NOTES: This is dependent on the extent that nitrates and phosphates get transformed or bound to sediments.

15. Transnational 3 6 9

NOTES: The major exception to this is the Great Lakes, which aren't a significant part of the problem.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences   3 6 9

NOTES:

REFERENCES:

Waite, Thomas D., 1984, Principles of Water Quality, Academic Press, Inc., Harcourt Brace Jovanovich, Publishers, Orlando.

McCaull, Julien and Janice Crossland, 1974, Water Pollution, Harcourt Brace Jovanovich, Inc., Publishers, New York.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Freshwater - Sedimentation

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

Notes: Flows from US to Mexico. From upper Mississippi to Gulf.

3. Concentration 1 2 3 4 5 6 7 8 9

Notes: 4 billion tons of waterborne sediment annually in US. 3 billion tons originate in agriculture. 3.6 billion tons soil eroded annually, 2.7 billion from agriculture. Of 3.9 billion annual tons of erosion, 3.7 billion from agric. and grazed forestland. [3 different estimates cited in Crossen (1982)]. Thus, R ranges from 3 to 12.

4. Persistence 1 2 3 4 5 6 7 8 9

Notes: Increased sediment remains in river systems unless removed by humans.

5. Recurrence 1 2 3 4 5 6 7 8 9

Notes:

6. Rate of Change
 in material flux 1 2 3 4 5 6 7 8 9

Notes: Same number of increases as decreases for suspended sediment between 1975 and 1981. Cropland erosion is increasing at a rate of 1-2%/yr. (Crossen)

7. Population at risk 1 3 5 7 9

Notes: Although sediments sometimes carry toxics, nitrates, etc., these problems are being evaluated under those problems.

8. Land area at risk 1 3 5 7 9

Notes: Non-point sources are responsible for 100% of sedimentation. 29% lakes and rivers affected by non-point sources. Interpret as water resource at risk.

9. Delay 1 2 3 4 5 6 7 8 9

Notes:

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

Notes: No significant effects, except as carrier of toxics which is considered elsewhere.

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

Notes: No significant effects, except as carrier of toxics, which is considered elsewhere.

12. Natural ecosystem impacts 3 6 9
(current annual)

Notes: Increased turbidity, reduces light reaching plants, decreases productivity. Sediments settling to bottom can smother bottom life.

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

Notes: "450 million cubic yards of sediment dredged annually from rivers and harbors in US. Cost of $250 million. Reduction of useful life of reservoirs by siltation , $50 million per yr. plus other damages. Total is $500 million in 1960's $. Pollution of surface water by sediments from farm fields costs society billions of dollars annually. (Cons. found., p. 361). $3.2B-$13B annually. Building of storage capacity for sedimentation. $300 - $700 M annually (Cons. Found., p. 362). Total offsite cost of soil erosion amounts to $6.1B per yr. (Cons. Found., p.105).

14. Transgenerational 3 6 9

Notes: Need for dredging, etc. in future.

15. Transnational 3 6 9

Notes: Except for Great Lakes & Columbia River, little effect to US from other countries.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

Notes:

17. Commitment to Future Ecosystem Consequences 3 6 9

Notes: Farming practices not likely to change soon enough to prevent continued significant erosion over next generation.

18. Magnitude of Future Consequences 3 6 9

Notes:

REFERENCES:

Crossen, Pierre R., 1982. The Cropland Crisis - Myth or Reality.
Johns Hopkins Press, Baltimore, MD.

Conservation Foundation, 1987, State of the Environment: A View Toward the Nineties. Washington,DC.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Ocean Water Quality

1. **Intentionality** 3 6 9

NOTES: Includes pesticides.

2. **Spatial Extent** 1 3 5 7 9

NOTES: Mixing and currents can transport wastes over hundreds of kilometers. They can also be transported long distances by the migration of marine organisms. (OTA, 1987)

3. **Concentration** 1 2 3 4 5 6 7 8 9

NOTES: Some of the organic pollutants do not exist in nature.

4. **Persistence** 1 2 3 4 5 6 7 8 9

NOTES: Contaminants of sediments with metals and some organic pesticides may be irreversible. (OTA, 1989)

5. **Recurrence** 1 2 3 4 5 6 7 8 9

NOTES: Many of discharges are continual.

6. **Rate of Change in material flux** 1 2 3 4 5 6 7 8 9

NOTES: Quantity of domestic sewage dumped in estuaries and coastal water has increased. In open ocean, industrial waste dumping has decreased dramatically, dumping of sewage sludge has steadily increased. Mixed trends, some areas improving, some continuing to degrade. Overall trend by weight is a slow increase. (OTA, 1987)

7. **Population at risk** 1 3 5 7 9

NOTES: "Millions of people can be effected directly or indirectly each year." (OTA, 1987)

8. Land area at risk 1 3 5 7 9

NOTES: Measures coastal and estuarine waters at risk. 82% of estuarine and coastal waters support designated uses. (Conservation Foundation from U.S. EPA, 1984). 13% of estuaries are moderately or severely effected by non-point sources. I will score this "5" based on "ocean water" resource at risk, although it is interesting to note that all coastal states have discharges into estuaries and/or coastal waters.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Toxics are biomagnified. These can cause cancer. Thus, there is considerable delay between release and effects.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Little documentation. U.S. EPA (1987) estimates only 2 cancer cases per year from ocean disposal of sewage sludge.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Little documentation, although there is speculation of a larger effect than this. Possible illness from ingestion of contaminated seafood and swimming in contaminated waters.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: OTA report discusses decline of populations of various forms of marine life, and less diversity at specific sites, but not mention of species extinction./

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Recreation damages greater than $1B. Commercial fishery damages $10M to $1B.

14. Transgenerational 3 6 9

NOTES: Due to persistence of chemicals, toxics and plastics in the marine environment.

15. **Transnational** 3 6 9

NOTES: Does not appear to have significant contribution from other countries, although transport distance would make this a possibility.

16. **Commitment to Future Human Health Consequences** 1 3 5 7 9

NOTES: From persistence of carcinogens in the environment.

17. **Commitment to Future Ecosystem Consequences** 3 6 9

NOTES:

18. **Magnitude of Future Consequences** 3 6 9

NOTES: Most problem substances in marine environments are persistent. (OTA, 1987)

REFERENCES

Office of Technology Assessment. Wastes in Marine Environments. Washington, D.C. 1987.

U.S. Environmental Protection Agency. Unfinished Business. 1987.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Soil salinity, alkalinity, waterlogging

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: The salt and alkaline substances resulting from one farmer's harmful irrigation habits can wash into a major river basin and affect farmers further downstream who use the same water for more irrigation--a major river basin like the Colorado should get the "subcontinental" rating since approximately 500 to 1000 km.

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: The natural background amount of salt, etc on prime cropland is fairly low The literature indicates affected US farmland has a range of 3 to 4 times the amount of natural salinity, alkalinity and waterlogging

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Some severe problems of this type are still present in what is now Iraq resulting from irrigation practices over 7,000 years ago. Most lands can be cleansed by natural rains after irrigation has stopped and the underground water table falls.
In the US, far less than 20% (if any) of that severe of a problem exists so it did not score a 9 but rather an 8--almost all US land could recover in less than 100 years

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: 1-1.5% per year increase in this problem on irrigated land in the US

7. Population at risk 1 3 5 7 9

NOTES: No one in the US suffers from the change in VEC (loss of soil productivity) through starvation. This does not effect American farmers' ability to produce enough food

8. Land area at risk 1 3 5 7 9

NOTES: 30% of the irrigated lands in the US are affected by the problem--45 million acres of land are irrigated in the US so approximately 13.5 million acres affected. The total amount of US cropland is 469 million acres.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Any amount of salinity, alkalinity, or waterlogging above natural level in the land can reduce crop yields (perhaps not a lot if the problem is just beginning but less food can be grown per acre) The time chosen for Delay is the time period of a growing season plus shipping to consumers

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: The US produces enough food to meet its domestic needs without importing--whether the food gets to all US citizens is another matter

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: *See note for #10 above

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Much of the crop damage from salinity occurs in the Colorado River Basin--the Bureau of Reclamation has estimated approximately $33 million per year in damage due to salinity, alkalinity and waterlogging

14. Transgenerational 3 6 9

NOTES: When farmland loses productivity due to salinity, alkalinity and waterlogging (as is the case now), reduced yields will be the situation for a long time to come

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

REFERENCES

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Soil Productivity, desertification_

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Average size of a US farm is 463 acres which is a approximately 1.8 square kilometers. Although the scale is not in area units for this descriptor, will score it a 1.

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Deforestation is not above maximum sustainable yields and the amount of forest in the US has increased since WWI (R<1 in that case) Erosion (the average of cropland and pasture) is at a rate of 7 tons/acre--the maximum sustainable yield set by the Soil Conservation Service is 5 tons/acre

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Depends heavily upon the extent of erosion -- Some of the land may never recover to former state from man's activities (which would score 9 on this scale) but in the US only a very small fraction (1-2%) is as bad as this

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Increasing at a rate of 1.5%/year for cropland erosion; grazing on cropland at about 1%/year Cropland erosion accounts for almost all of the problem

7. Population at risk 1 3 5 7 9

NOTES: No one in the US suffers from the consequences (health problems) because American farmers cannot produce enough food

8. Land area at risk 1 3 5 7 9

NOTES: Erosion exceeds tolerable levels on about 1/2 of US cropland US cropland = 469 million acres
The other types of land in the US (forests, pastureland, rangeland) are affected little by the soil productivity problem and their combined total would not be enough to push the ranking past 70% on the scale

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Time period during which a crop would usually be planted, harvested and shipped to consumers--the assumption being that loss of soil productivity is going to affect the nearest planting time for a farmer and the consumers would then have a smaller supply of food at the end of the season

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No one in the US dies from starvation because US farmers cannot produce enough food on the US cropland--whether or not everyone in the US has enough food is a matter of the supply procedures

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: See note for #10

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Although the soil productivity problems has an impact on cropland, it is very small on forestland and pasture (within tolerable levels)

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 5% crop yield lost over 50 years--approximately .1% per year of the total value of agricultural goods produced in the US
Total US value of agricultural goods is 70.7 billion/year
(.001)(70.7 billion) = 70.7 million/year GNP = 4.525 billion/year

14. Transgenerational 3 6 9

NOTES: The loss of soil productivity is a problem in which a resource is lost that may take decades to renew itself if it does at all

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

REFERENCES

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Quantity of arable land

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Average size of US city--regional on the scale

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Difficult to find a "maximum sustainable yield" for losing cropland Assume the 300,000 acres/year lost to urbanization is not close to what the US could lose before not being able to meet domestic food supplies

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Cities have a tendency to stay on the cropland for a very long time

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: took about 15 years to decrease from 2 million acres/year to around 1 million acres/year of urbanization taking away cropland A .05%/year decrease

7. Population at risk 1 3 5 7 9

NOTES: No one in the US is experiencing health consequences through starvation due to productivity losses experienced by farmers because of urbanization

8. Land area at risk 1 3 5 7 9

NOTES: Approximately one million acres per year taken away from cropland

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Time period during which a crop would usually be planted, harvested and shipped to consumers after a piece of land is removed from agriculture

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No one in the US is experiencing health consequences through starvation due to the productivity losses experienced by US farmers

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: See note for #10

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 300,000 acres/year of cropland lost to urbanization If I consider this "prime" cropland, a good yield is 250 bushels/acre of corn at a world mkt price of $3.75/bushel (alfalfa, soybeans, wheat about the same return) 300,000*250 bushels/acre*3.75=281 million dollars lost in agricultural value US GNP=4526 billion. The concern of a full cost benefit analysis not being done here is great--the land could be equally or perhaps more productive economically than when it was being used to grow crops.

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: #9 QUANTITY OF ANIMAL HABITAT

[See Summary Notes at end.]

1. Intentionality 3 6 9

NOTES:
Intent to harm trees, plant life in deforestation and wetland conversion. Harm to animals is unintended but foreseeable and unavoidable consequence.

2. Spatial Extent 1 3 5 7 9

NOTES:
Dams affect environment for long distances, with fishing harvests affected over 100 km. away; wetland draining can affect large areas.

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES:
In the USA, 395 parks and reserves totalling 79.1 million hectares (195.5 m acres), all of which are over 1000 ha in size, are considered by the IUCN to be protected areas for nature conservation. (UNEP 89/90, p.237, 296-99) This amounts to approx. 8.3% of the country that is well protected. At least 5 reserves protecting over 1000 sq km are found in each of the IUCN biogeographical zones found in the USA (WRI86, pp. 95-97). 32% of the nation is forested woodland and 26% is grassland, some of which is habitat(OECD89, p.99). These figures suggest that <u>the status quo may be a fairly "safe" level</u>.

Between 1970 and 1985, protected wildlife areas (IUCN lands category I-V) were increased at a rate averaging 27,666 sq km per year (OECD89, p105). Much of this land was unspoiled habitat to begin with, but some would presumably have been converted to other use (or was reclaimed from other uses) without its formal protection designation. Therefore, some % of this amount may be considered as additions to wildlife habitat.

Losses of habitat occur mainly in deforestation and wetland conversion activity. Of 95 million acres of wetlands remaining in the 48 states (originally 215 ma), .3 to .45 ma are converted per year for a loss of 0.4% annually. (State of the Environment, pp 291, 366-369; 395,200 acres: OECD Compendium 1989, p. 101) Ancient forests, especially in the Pacific Nothwest, are being cut at the rate of 60,000 acres per year (Sci Am p.112).

In general, other land use patterns have stabilized (OECD Comp. 1989, p.99). Assume, therefore, losses of approx. 0.5 m acres per year. Gains are some % of the 27,666 sq km (6.8 m acres) of protected area additions -- if 7%, then rough equilibrium exists.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES:

Wetlands may be irretrievable; reforestation takes up to a hundred years (Scientific American, p. 112).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

Ongoing activity.

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES:

Unclear. Wetland conversion rate and deforestation of old-growth forest occurs at constant rate. Preserves being added, at rate directed by political forces. More research needed, but assume constant rates.

7. Population at risk 1 3 5 7 9

NOTES:

Animals are primarily at risk from lost habitat. People will ultimately bear the many of the costs of lost animal habitat, but it is unclear what "at risk" means in this context.

8. Land area at risk 1 3 5 7 9

NOTES:

Assume protected lands (8/58) are not at risk while some % of the remainder is. Thus, some % of the 86% of habitat that is not formally protected is at risk. Assume 50% = 43%.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Immediately for affected plant species, some wildlife. Until next breeding season for wildlife.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Lowest score unless subsistence hunters experience starvation.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
See 10 above.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Species extinction.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Loss of wildlife habitat would affect $30-40 billion/year "wildlife associated recreation," which includes hunting, fishing, birdwatching, etc. Some impact on fur and animal products industry? More research needed, but current assumptions are that habitat losses are offset by additions. No welfare effects. Also, losses are primarily considered under stock of wildlife.

14. Transgenerational 3 6 9

NOTES:
Species extinction.

15. Transnational 3 6 9

NOTES:
USA responsible for its own habitat destruction.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

Some % of medicines are animal based; potential losses to future health from foregone medicines?

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

Ongoing depletion of animal habitat implies extinction.

18. Magnitude of Future Consequences 3 6 9

NOTES:

Increased probability of extinctions.

SUMMARY NOTES:

[Note: re. intent: problem here might be called "double effect" -- if one's actions will directly result in the destruction of living things, even though such destruction is not one's primary intent, this should count as a 6.]

[Re. concentration: Unclear what "safe or sustainable level" means here; "maximum sustainable yield" seems senseless, as does "sustainable levels." The general idea we want to capture seems to be whether the change in flux is acceptable or not in terms of the preservation of high quality wildlife habitat. Ideally, experts examining a country's wildlife habitat -- and the tradeoffs between preservation and development -- could estimate the percentage of habitat that should be preserved. See AMBIO vol XI, 11/5 82 Therefore, the "safe level" will be considered as the status quo and this descriptor measures gains or losses to the existing amount.]

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: U.S.A.

ENVIRONMENTAL PROBLEM: 10. Pure Food

1. Intentionality. 3 6 9

NOTES:
Pesticides are intended to harm pests.

2. Spatial Extent 1 3 5 7 9

NOTES:
65% of pesticides are applied by air and travel long way (WRI89, p.30). Additionally, PCB's and other long lasting compounds are nearly ubiquitous; a single release can have far ranging effects.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
No natural background for most pesticides, other pollutants. Safe levels exceeded by many compounds. DDT and BHC are widely restricted, but found in wildlife, human tissue and human milk.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
DDT, PCB's last long time. DDT, restricted in early 70's, still widely found.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Continual application of pesticides; improper disposal and accidental releases of other compounds.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Trends in pesticide consumption over 4 years '77-'81 were up 14%; 3.3% annually and 22 year doubling time. (OECD

Environmental Data Compendium, p.299). Although different compounds are increasing/decreasing in use, many (incl. various pesticides, DDT, HCH, PCB's) are relatively constant in dietary intake of Americans between 1980-85 (UNEP90, p.197). This data suggests either a slight increase or constant amount of impurity in foods; score 6.

7. Population at risk 1 3 5 7 9

NOTES:
EPA UnfBus App2 ranks only three pesticides, two with up to 10m and third over 10m. PCB's found in almost 100% of population (UNEP87, p.100).

8. Land area at risk 1 3 5 7 9

NOTES:
Resource at risk is pure food (agricultural produce and wildlife). Pesticides and PCB's are found in a very wide variety of animal products (incl. marine and freshwater fish, ducks, and shellfish). Data on contaminated agricultural produce is sparse, but data on human intake of contaminants suggests that contamination is widespread. Assume most of the resource is at risk.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Approx. 5000 cases of pesticide poisoning annually, with approx. 30 deaths. Unclear whether these figures refer to agricultural workers only, but assume some small level of poisoning due to ingestion (Costa, p.17).

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
EPA Unf Bus est. that 50% of cancer cases die (see 11 below). Mortality receives a low 6, while morbidity receives a high 6.

11. **Human morbidity** 1 2 3 4 5 6 7 8 9
(current annual)

NOTES:
EPA est. 6000 cancers annually (EPA App I, p.4). EPA App II estimates additional non-cancer morbidity on the scale of 10 to 1000 for three different pesticides. Costa indicates 5000 poisonings annually, some assumed to be from ingestion (Costa, p.17).

12. **Natural ecosystem impacts** 3 6 9
(current annual)

NOTES:
Experienced extinctions, esp DDT.

13. **Welfare effects** 1 2 3 4 5 6 7 8 9
(current annual)

NOTES:
2% of GNP is from agriculture: $80 billion. $282 million lost in 6 states reporting contamination between 1968-79 (Environmental Contaminants in Food, OTA 1979 Wash. DC, p.26: this figure is termed a "gross underestimate.") Assume ave. loss per state is $282/6 = $47 million, over 11 years is $4.3m/state/year. For 50 states, $213 million per year is very rough est.

14. **Transgenerational** 3 6 9

NOTES:

15. **Transnational** 3 6 9

NOTES:

16. **Commitment to Future Human Health Consequences.** 1 3 5 7 9

NOTES:
CENTED predicts potential mortality > current annual.

17. **Commitment to Future Ecosystem Consequences.** 3 6 9

NOTES:
Continuing extinctions.

18. **Magnitude of Future Consequences.** 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Ultraviolet energy absorption
(stratospheric ozone depletion)

1. Intentionality 3 6 9

NOTES: CFC's are inert, not harmful to humans or other organisms.

2. Spatial Extent 1 3 5 7 9

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: CFC's are unknown in nature.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Atmospheric residence time for CFC11 & CFC12 -> 75-110 yrs. Others degrade more rapidly. CFC11 & CFC12 have greatest ozone depletion potential. (Miller & Mintzer).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Releases are continuous.

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: Montreal Protocol - 50% reduction from 1986 levels by 1998. Helsinki Declaration calls for complete elimination by 2000. This is non-binding. The Protocol controls the CFC's that are most damaging to the ozone layer. In addition, it freezes halons at 1986 levels starting in 1992.
OTA (1987) analysis of trends in CFC11 & CFC12 in response to Montreal Protocol: (change from 1986 levels)

1999: -35% to -15% : -2.7%/yr. to -1.1%/yr.
2009: -45% to +20% : -2%/yr. to +0.9%/yr.

based on scenarios of # of signatories, growth in "Article 5" countries and, compliance.
See also, EPA, "Future Concentrations of Stratospheric Chlorine and Bromine", EPA 400/1-88-005, Washington, DC, Aug., 1988.

7. Population at risk 1 3 5 7 9

NOTES: Entire population at risk for some of the health effects. Only white-skinned at risk for some of the cancers.
Greater than 10,000,000 at risk. (EPA UB)

8. Land area at risk 1 3 5 7 9

NOTES: The entire nation will be affected by decreases in ozone layer.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: For cancer and other human health effects, years.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Although the decline in stratospheric ozone is contributing to future health problems, it has not yet conclusively been linked to current health problems. This is because of the long time period over which cancer develops.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: See notes under human mortality.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Increased UV-B results in decreased productivity. But these don't appear to be significant currently for natural ecosystems.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 0.3% decrease in yields of soybeans per 1% increase in UV-B (EPA UB). Assume 0.3% decrease in all crop output. Total agricultural crop value is 62.9×10^9. With 3% decline in ozone layer, there is 0.9% drop in agricultural productivity which is worth 566×10^6. As all crops don't decline, this may be an overestimate. On the other hand, it does not place a value on material damages.

14. Transgenerational 3 6 9

15. Transnational 3 6 9

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Even in the absence of further ozone depletion, future health consequences over the next century include melanoma and non-melanoma skin cancer.

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Long-range changes unknown. Expect decreased productivity of phytoplankton, effects on fish larvae. Experiments on plants show adverse reactions to UV-B. Likely change in competitiveness of various plants, changing ecosystem structure and function (EPA UB).

18. Magnitude of Future Consequences 3 6 9

REFERENCES:

Miller, A. & Mintzer, I., The Sky Is the Limit, WRI RR #3

Rowe, R,D, and Alans, R.M., Analyses of Economic Impact of Lower Crop Yields Due to Stratospheric Ozone Depletion, draft report for US EPA, Aug., 19887.

US EPA, Assessing the Risks of Trace Doses that Can Modify the Stratosphere, Washington, DC, 1987.

US EPA, Regulating Impact Analysis: Protection of Stratospheric Ozone, Washington, DC, Aug. 1, 1988.

OTA, An Analysis of the Montreal Protocol on Substances that Deplete the Ozone Layer, Staff Paper, Feb. 1, 1988.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Thermal Radiation Climate Change Budget Alteration

1. Intentionality 3 6 9

NOTES: None of these activities intended to harm non-humans, although some, such as deforestation, indirectly have this effect.

2. Spatial Extent 1 3 5 7 9

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Concentration of GHGs prior to large human impact (approx. 1800).
CO_2, yr. 1800, approx. 280 ppm; yr. 1985, approx 340 ppm.
340/280 = 1.2.
CH_4. 1800, approx. .8, 1985, approx. 1.6
1.6/.8 = 2
N_2O. 1800 approx. 290, 1985 approx.315.

References: CO_2 from Trabalka, 1985. CH_4 and N_2O from Darmstradter.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: CO_2 is not photochemically active. Anthropogenic emission alter biogeochemical cycles. CH_4 lifetime 5-10 yrs. N_2O lifetime, 100-175 yrs. CFC lifetimes- up to 110 yrs.

References: EPA Stabilization Report

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Releases are continuous.

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: For CO_2, over past couple years, rate of growth is 3-4% per year. For CFC, trends are unclear - formerly increasing, but with Montreal Protocol may be decreasing. CO_2 is over half of the problem. Atmospheric concentrations of other GHG's increasing, but data on emissions not available.

7. Population at risk 1 3 5 7 9

NOTES: Although regional and sectoral impacts are uncertain, all of the population is potentially exposed to the effects of climate change.

8. Land area at risk 1 3 5 7 9

NOTES: Regional impacts unknown. All land area at risk.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Climate change is likely to occur in the future, sometime in the next century, due to today's releases combined with future releases.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No current effects. At least none that can be substantiated with any certainty.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No current effects. At least none that can be substantiated with any certainty.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: No current effects. At least none that can be substantiated with any certainty.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No current effects documented.

14. Transgenerational 3 6 9

NOTES: Current releases of GHGs will cause climate change in future.

15. Transnational 3 6 9

16. Commitment to Future Human Health Consequences — 1 3 5 7 9

NOTES: No known health effects in US. Probably wealthy enough to avoid significant death from starvation due to drought, floods, etc.

17. Commitment to Future Ecosystem Consequences — 3 6 9

NOTES: This depends on degree and rate of change in emissions. With current levels and rates, climate is likely to change quickly enough that some species will not be able to move with the climate or adjust.

18. Magnitude of Future Consequences — 3 6 9

REFERENCES:

Trabalka, John R., 1985, Atmospheric Carbon Dioxide and the Global Carbon Cycle, DOE/ER-0239.

Darmstadter, et al., Impacts of World Development on Selected Characteristics of Atmosphere.

U.S. EPA. 1987. Unfinished Business.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Acidification - Acid Rain

1. Intentionality 3 6 9

NOTES: Fossil fuel combustionn, various industrial activities not intended to harm non-humans or humans.

2. Spatial Extent 1 3 5 7 9

NOTES: 1/3 from > 500km; 1/3 from 200-500km; 1/3 from < 200km. (OTA, 1984.)

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Concentration: Anthropogenic sources account for 90% of sulfur, 80% of nitrogen in atmosphere in Eastern US.

Concentration ratios: SO2: 25
Particulate matter: 25, 26
Acid aerosols: 100

From Ivanov & Freney: (mgS/m3)

	SO2	SO4	total
Continental clean:	.2 +- .1	.6 +- .2	.8 +- .3
Industrial:	5. +- 2.	3 +- .5	8 +- 2.5

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: 3-5 days.

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Releases are continuous.

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Emissions: SO2 NOx (millions tons/yr) (OTA, 1984)

Emissions	SO2	NOx	
1970	30	19	49
1990	28	21.5	49.5

Clean Air Act could change this!

7. Population at risk 1 3 5 7 9

NOTES: SO2: 2.8×10^5

Particulates, acute: 3×10^6

Particulates, chronic: 1.2×10^7

Acid aerosols: 1×10^7

(OTA, 1984. For more detailed look, see Brookhaven.)

8. Land area at risk 1 3 5 7 9

NOTES: Eastern half of US has precipitation ph < 5.5.
25% of land area in Eastern US is sensitive to this.
1/4 of 1/2 = 1/8.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Varies, depending on buffering capacity of soil or lake. Current releases contribute directly to damages in most sensitive areas. Further research needed.

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: From current levels of sulfates & other particulates, 50,000 premature deaths (2% of total deaths per yr.) in the US and Canada. Score "5" because some are in Canada and not all are from sulfates.

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: No health effects yet associated with nitrogen oxides. OTA report gives deaths but not illness. Assume an order of magnitude higher illnesses to generate these deaths. Further research needed.

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES: Although many lakes die & terrestrial ecosystems are damaged, there is not talk of species extinction related to this.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

Acid. wet dep. materials:	2.8B
SO2 dry dep. materials:	1.7B
NO2 dry dep. materials:	10M-1B
Fishing (not resource):	1M-100M
Crops:	10M-100M
Forests:	100M-1B
Fisheries (comm.):	1M-10M
SO2 crops:	1M-10M
SO2 forests:	1M-10M
	$4.62B-$6.73B

Also, sulfates are the largest contribution to visibility, which has an estimated cost of $1.5B-$8B. (EPA UB)

14. Transgenerational 3 6 9

NOTES: A cessation of sulfur emissions will not result in full recovery of ecosystems within one generation. Recovery of lakes: 10-100 yrs.; streams, 1-10 yrs.; forests, 10-100 yrs. (EPA UB).

15. Transnational 3 6 9

NOTES: Canada contributes to US acidification.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Potential health effects from acidified drinking water due to its ability to leach toxic metals. A concern for wellwater. City water can be monitored and purified. This is an uncertain effect. Therefore, I would say no harm established, although there is a potential harm. (OTA, 1984)

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Acidification is a cumulative problem. Therefore, today's emissions will conntribute to future ecosystem effects.

18. Magnitude of Future Consequences 3 6 9

NOTES: Reductions in emissions lead to improvements in many acid-altered lakes. Although there is much talk of a clean air act which would reduce SOx and NOx emissions, it has yet to be passed. Perhaps after its passage, we can score this "3".

REFERENCE

OTA, Acid Rain & Transported Air Pollutants, 1984.

Menz & Mullen, "Acidification Impact on Fisheries: Substitution & the Valuation of Recreation Resources" in Thomas D. Crocker, ed., Economic Perspectives on Acid Deposition Control. 1984, Butterworth, Stoneham, MA, Publishers, Acid Precipitation Series Vol. 8

Chris C. Park, Acid Rain, 1987, Methuen & Co., Ltd., London.

Brookhaven National Laboratory, Biomedical & Environmental Assessment Division, "Long Range Transport Air Pollution Health Effects", OTA contractor report, May 1982.

U.S. EPA. 1987. Unfinished Business.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Photochemical Oxidant Formation (Urban Smog)

1. Intentionality 3 6 9

NOTES: Major activities leading to this not intended to harm.

2. Spatial Extent 1 3 5 7 9

NOTES: "Industrial or urban ozone can contribute to high ozone levels hundreds of miles away. (200-250 miles). NOx transported 100 miles. VOCs transported a few to hundreds of miles, with distant sources less important than fresh emissions (OTA, 1989).

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: (CENTED gives NOx from coal = 5)
Concentration ratios: ozone, acute: 100; chronic: 292 (EPA UB).
For polluted urban air: NO is 1000 to 15,000. NO2 is 500 - 1000. (Seinfeld)

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: NOx summer atmospheric lifetime 6-10 hrs. VOC lifetime, less than an hour to several days, with fastest reacting (shortest lifetime) producing the most ozone (OTA, 1989).

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Releases are continuous.

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: For NOx: estimates 1985-2004 rise by 25%, about 1%/yr.
1985-1994 rise by 5%, about 1/2%/yr.
VOC emissions currently holding steady.
Clean Air Act could change this! (OTA, 1989)

7. Population at risk 1 3 5 7 9

NOTES: 35 million exposed to ozone above the standard, avg. 9 hrs./yr. 130 million live in area where ozone concentrations reach or exceed the standard.

US pop. is approx. 250 million. Use 130/250 = .52. This is the population potentially exposed due to living in a non-attainment area. They are exposed in the sense that if they were outside at proper moment they would be exposed. (OTA, 1989)

8. Land area at risk 1 3 5 7 9

NOTES:
30 ppb natural background over cropland in summer
>30 ppb in about 50% of land area
>40 ppb in about 30% of land area
>50 ppb in about 5% of land area. (OTA)

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Highest concentrations are often observed after more than one day of hot, sunny conditions. Answer to this dependent on the mix of VOC's and NOx and chemistry (which is dependent on weather). (OTA)

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Great uncertainty whether this leads to any increased death. It is thought elevated ozone levels may lead to premature aging of lungs and other chronic health effects. No proven effects yet. No estimates of increased mortality.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: If standards were met in all areas, avoid several hundred million incidents of respiratory symptoms. 8 to 50 million days each year when someone's activities are restricted. (OTA, 1989).
8/250 = .03 50/250 = .20
These are cases, not individuals effected. A score of "7" is thus a conservative number.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Injury to tree species in US (Canada & Europe) including: Ponderosa & Jeffrey Pines in San Bernardino Mtns. & strains of white pines throughout the Eastern US (OTA, 1989)

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 25% of difference between current & bkg levels, $.5-1B benefits in decreased crop loss (OTA 1989).
$10M-1000M materials damage
$100M- >1B crops
$10M-100M forests
(EPA UB)

14. Transgenerational 3 6 9

NOTES: No known health effects will affect offspring. Ecosystem damage may take longer than one generation to recover, but recovery could be under way immediately with cessation of polluting activity.

15. Transnational 3 6 9

NOTES: Do we get significant NOx or VOC's from Canada? With transport on the order of 200 miles, I would guess that we get some, but that it is a minor part of the problem. Unlike acidification, elevated ozone is a problem throughout the U.S., making any Canadian contribution in the Northeast much less significant.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Elevated ozone is suspected to contribute to premature aging of lungs, leading to prolonged illness. This would give a score of "5". However there is much uncertainty here-- these results are inconclusive. Therefore, score "1".

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Ecosystems will recover if today's emissions stop.

18. Magnitude of Future Consequences 3 6 9

NOTES: If stopped activity today, there would not be future consequences.

REFERENCES:

OTA. 1984. Acid Rain & Transported Air Pollutants

OTA. 1989. Catching Our Breath

U.S. EPA. 1987. Unfinished Business

Seinfeld, John H. 1986. Atmospheric chemistry and Physics of Air POllution. John Wiley & Sons, New York.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: Concentrations of Toxins (Hazardous &Toxic Air Pollutants)

1. Intentionality 3 6 9

NOTES: Some of these come from the manufacture of biocides such as pesticides, herbicides, anti-bacterial cleaning solutions.

2. Spatial Extent 1 3 5 7 9

NOTES: There is long distance transport. For lead, 40% near fallout, 8% in metro area, 24% more widely dispersed, with residence time of 1-2 weeks (Elson). U.S. EPA uses 50 mile radius for significant health effects. (Discussion with Gary Marchant).

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Ratio scores: lead: 1.7, carbon monoxide: 4.8,
toxic & hazardous air pollutants: Benzene: 12,
carbon tetrachloride: 10, chlorine: 170, chromium: 3,
Formaldehyde:13,300, Hydrogen sulfide: 232, (EPA UB)
Some of these substances are not found in nature.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Residence time of lead = 1 to 2 weeks. Data on other toxins would be helpful.

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Many releases are continuous.

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: Lead is decreasing. Incidence of toxins not well documented. Therefore, no information on trends. The Clean Air Act (current version, if passed) would control stationary sources which are estimated to cause 50% of the health effects. Compromise seems to have been reached on Toxic aspects of the bill, with maximum available control technology required. This will lead to 90% emission reductions of those toxics that are controlled. Estimated reductions of 30 - 50% over the next few years. (Discussion with Gary Marchant). Thus, this would score "1" if legislation if passed.

7. Population at risk 1 3 5 7 9

NOTES: Urban population is high end estimate = 76.9%. Large population exposed (EPA UB). Children exposed to lead: 2680, carbon monoxide: 3×10^6, toxics: 1.7×10^8 to 2.3×10^5.

8. Land area at risk 1 3 5 7 9

NOTES: Due to long-range transport, and sources all-over the nation, fair to assume that the entire nation is at risk, although some areas receive higher concentrations.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Many of the pollutants cause cancer, which has a significant delay between release & consequence.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Cancer mortality is 50% of total cancer cases (US Dept. of Health & Human Services, 1988). 0.5 x 2000 = 1000

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Annual cancer incidents - 2054 (EPA UB)
1300-1700 cancer cases per yr. (Cons. Found., 1987). This study covered only a fraction of the toxic substances present in outdoor air, but it made conservative assumptions in estimated risk (thus a countervailing possibility of overestimates).

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Most well-known example is DDT. Other airborne toxics such as PCB's have been shown to have adverse ecosystem effects.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Lab studies point to evidence of crop damage (EPA UB).
Lead: material damage: $100M-1000M
crops: $1M-100M
forests: $1M-10M
ag. land: $1M-100M

14. Transgenerational 3 6 9

NOTES: Due to longevity in environment.

15. Transnational 3 6 9

NOTES: Due to long-range transport. Similar to reasoning under ozone. Contributions from Canada or Mexico will be small compared to the total problem.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Some of the toxic pollutants are suspected of being genotoxins. e.g. dioxin.

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Many of these substances are long-lived in the environment and will continue to have adverse ecosystem effects in the future.

18. Magnitude of Future Consequences 3 6 9

NOTES: Due to increased use of toxic chemicals over the last two decades and the time lag for cancers to develop, we would expect future consequences to be more severe. The clean air act could change this.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Indoor air quality - radon

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Levels above backgrounds are inside buildings

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Depends on foundation type of the building, pathways for air transport from soil to basement, source of water supply and average ventilation rate. The average concentration in the US is 1.5 picocuries/liter although some people live in structures with concentrations much higher. The natural background of radon is .15 picocuries/liter

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Radon has a half-life of 3.82 days The isotope of radon decays into radon daughters which are solid, short-lived. Two of these daughters (polonium-218 and polonium-214) emit alpha particles and last for 3.05 minutes and .000164 seconds respectively

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: Radon decay continues constantly from natural sources

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: The natural decaying process has not changed

The Department of Energy has stated that the new, energy-efficient structures that were built in the 1970's (and continue to be built) have a 50% less air exchange ratio between outside and inside air. The air exchange ratio plays a major role in determining the level of concentration of radon inside a structure. The resulting score is my judgement that the energy efficiency issue has the radon accumulations increasing.

7. Population at risk 1 3 5 7 9

NOTES: Estimates of 200 million Americans

8. Land area or resource at risk 1 3 5 7 9

NOTES: Resource at risk is indoor air quality--virtually all of it is affected with some concentration of radon gas but score it a "7" since not all of the indoor air is effected with significant levels of radon.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: The EPA uses models which specify a minimum of 10 years for latency period between exposure and cancer

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: The survival rate for cancer among the US population is 49.5% (an average of men=55%, women=44%) The EPA estimates 20,000 cancer cases per year from radon--took the survival rate times the cases of cancer (49.5% * 20,000 = 9900)

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: The number of lung cancers induced by radon per year estimated to be 20,000.

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Testing costs approx $50 and $2500 to install a soil-ventilating system Lowering of property values of $2500 per house may occur EPA estimates 10 million homes in the US have a problem ($2500*10 million = 25 billion dollars) Must have a per year figure so say that it would take 10 years for 10 million homes to fix ventilation system=2.5 billion per year. The US GNP is 4525 billion *Probably underestimated since the affect on other property values (commercial) were not quantified--raise the score to a "7".

14. Transgenerational 3 6 9

NOTES: Chromosomal anomalies may spread over many generations

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences — 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences — 3 6 9

NOTES:

18. Magnitude of Future Consequences — 3 6 9

NOTES: The number of cancers the US is likely to experience from radon in the 1990's will be greater, in my judgement, than the number experienced in the 1980's due to radon. Assume that the US citizens whose cancer revealed itself in the 1980's were exposed probably in the time period before and including the late 1960's (EPA uses a 10 year latency period between exposure and the outward manifestation of cancer signs) The citizens whose cancer will reveal itself in the 1990's were probably exposed in the late 1970's. The Department of Energy has stated that the structures built since the 1970's have been much more energy efficient (US concern with energy prices and conservation) than older structures built before that time period--in many cases the air exchange rate between outside and inside air is 50% less in the new, energy-efficient structures. Air exchange rate is a major factor in determining whether or not the structure has high concentrations of radon. Therefore the concentrations of radon probably got worse inside structures during the last 15 years (although no data confirming this) and a greater number of cancers will show up in the future than the US has today due to radon.

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Indoor air quality--nonradioactive

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: pollutants remain inside structures

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Took a weighted average of aldehydes, consumer products, asbestos and other fibers, indoor combustion particles, tobacco smoking, benzene, carbontetrachloride, nitrogen dioxide, tetrachloroylene, trichloroethylene, chloroform, xylene
and they all are over safety levels but ** the scoring on this descriptor is over background so there is no natural amount of the majority of these substances

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Could get satisfactory data on half of the items named in #3. Carbontetrachloride stays over 10 years. Perhaps one of the other pollutants not found could remain over 100. Does depend on the ventilation system of the structure--most structures would ventilate out the carbontetrachloride in less than a year.

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: Dept of Energy has estimated that the air exchange rates in new constructions are on average 50% lower than the national air exchange rate average and if this trend continues, the concentration levels of indoor pollutants will double. Indoor air pollutants are on the rise because of energy conservation, increased use of synthetic chemicals, ignorance of good ventilation and housekeeping practices

7. Population at risk 1 3 5 7 9

NOTES: Virtually all Americans are exposed to indoor air that is chemically contaminated

8. Land area at risk 1 3 5 7 9

NOTES: The resource at risk is structures in the U.S.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Tobacco smoke accounts for most of the total risk--smoke can cause some individuals to become nauseated, have severe headaches, catch colds easier, etc within a short amount of time
However, the most significant score is being used and some of the pollutants cause cancer--use EPA estimate of 10 year latency period between exposure and onset of cancer

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: The pollutants named in #3 totaled approximately 6100 deaths (mostly due to cancer) (EPA)

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: The cancer survival rate is 49.5% in the US--an estimate is 2*6100 = 12,200 cases then. 25% of US citizens get sick from formaldehyde annually (EPA)

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Indoor pollutants are a source of soiling and contribute to the deterioration and corrosion of equipment, furnishings and appliances. They also increase the cost of housekeeping which is usually 20% of the annual operating budget of a commercial firm. The cost of corrosion in the US is estimated to be 25 billion/year and indoor pollutants are said to be a "small" percentage of that--I estimated "small" to be .01% = 2.5 million/year

14. Transgenerational 3 6 9

NOTES: Some of the pollutants cause mutant genes which can show up generations later

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences — 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences — 3 6 9

NOTES:

18. Magnitude of Future Consequences — 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Exposure to chemicals in the workplace

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Chemicals remain inside the structure of the workplace

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Over 30,000 substances potentially risky to workers--the weighted average of 17 of these was taken and the concentration exceeds safety levels but ** the scoring on this indicator is over background and there is no natural amount of the majority of these chemicals

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Several of the pollutants remain a hazard for decades including many of the pesticides workers use

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

6. Rate of Change 1 2 3 4 5 6 7 8 9
in material flux

NOTES: Approximately 1800 Premanufacture Notifications of intent to manufacture new chemical substances are submitted to EPA each year. Of these, approximately half are actually used in commercial processes. From this information, my guess is that the number of new chemicals in the workplace (because EPA must approve) is steady or rising slightly.

7. Population at risk 1 3 5 7 9

NOTES: Approximately 122 million workers in the US--assumed 75% of workers are exposed to at least 1 of the 30,000 risky chemicals .75*122 million=91,500,000

8. Land area or resource at risk 1 3 5 7 9

NOTES: Assumed resource was the working environment

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Some of the chemicals can cause skin injuries in a few seconds but since the highest significant score is used here, I used the 10 year latency period for cancer onset estimated by EPA in their models

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 125 deaths from 7 of the 17 chemicals averaged in #3--EPA states the 7 chemicals is a large underestimation of the problem but the EPA could not find reliable data on the other chemicals
Since EPA stated this was probably an underestimation--move up one number on the scale to a "4".

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: 125,000 occupational illness/year in the US with the causes--42,600 skin diseases, 10,750 exposure to toxic agents, 4,650 poisoning, 1748 diseases of the lung, 21,335 other, 34,700 repeated trauma, 9,120 physical agents I excluded the last 3 categories (other, repeated trauma, and physical agents) and assumed the other illnesses most likely resulted from exposure to some of the thousands of chemicals in the workplace.
Total=59,748

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: ranked "low" by EPA which is in the 10 million range

14. Transgenerational 3 6 9

NOTES: Some of the chemicals examined by EPA could cause mutant genes

15. Transnational 3 6 9

NOTES:

16. Commitment to 1 3 5 7 9
Future Human Health
Consequences

NOTES: Mutant genes

17. Commitment to Future Ecosystem Consequences — 3 6 9

NOTES:

18. Magnitude of Future Consequences — 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Exposure to radiation (other than radon)

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Radioactive particles in air and water can travel throughout the globe as demonstrated by the Chernobyl accident

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: The level of radiation from natural background (inside the human body, rocks and soil (other than radon)) is about the same as the level of radiation from man-made sources

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: It will take millennia for certain radioactive isotopes to decay

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: The production of nuclear weapons has increased and the forty years accumulation of improperly stored nuclear waste (in storage tanks from the WWII era) is now leaking into land, water and air. UNEP reports a less than 1% increase per year in the building of nuclear power plants in the U.S.

7. Population at risk 1 3 5 7 9

NOTES: A source of radiation is consumer products (building materials, watches, etc) which means a large population

8. Land area or resource at risk 1 3 5 7 9

NOTES: The whole country

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Used the 10 year latency period for cancer modeling by EPA

10. Human mortality 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: EPA estimates 125 deaths from industry, medicine, research and defense plus consumer products

11. Human morbidity 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Took the number of EPA cancer fatalities and doubled since the survival rate is 49.5% for cancer at all sites in the US

12. Natural ecosystem impacts 3 6 9
(current annual)

NOTES:

13. Welfare effects 1 2 3 4 5 6 7 8 9
(current annual)

NOTES: Estimated to be "low" by EPA -- approximately 10 million per year

14. Transgenerational 3 6 9

NOTES: chromosomal anomalies may spread over generations

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Accidental Chemical Releases

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: If the chemicals were airborne or in the water, they can travel several hundred miles from point of release

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: EPA examined this problem and their estimates were in the range of 4-6 times the safety level but since this is scored by comparing the chemicals with a natural background level the score was high

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Some chemicals like carbontetrachloride (which has been involved in accidental releases) lasts longer than a decade as well as certain pesticides that have been accidently released in the US

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: the number of accidental chemical releases in the US averaged over the time period--approx 2 per year

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: In the 1970's, UNEP reports 14 major spills in the U.S. and in the period 1980-1987 inclusive there were 12 spills--difficult to draw a conclusion from this data so rated "no detectable change."

7. Population at risk 1 3 5 7 9

NOTES: EPA estimates 95-99% of the individuals at risk are chemical workers--1,026,000 chemical workers in the US

8. Land area or resource at risk 1 3 5 7 9

NOTES: Potentially exposed land area is high since transportation of chemicals occurs on the majority of US roads, railways and waterways.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: Some of the chemicals can cause cancer -- use EPA model of 10 year latency period

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: UNEP reports 1978 as the last time people died in a major chemical accident--the average over 27 years is approximately 2 people per year.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: EPA estimated 2700 injuries

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Further research needed but the accounts of specific accidental releases discussed losing habitat and death of wildlife. A better definition of "significant" in the categorical definition part of this desciptor is needed.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Estimated to be "moderate" by EPA 10-99 million/year so used 99 million

14. Transgenerational 3 6 9

NOTES: Several of the chemicals transported (tetrachloride for example) can cause mutant genes

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES: Mutant genes

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES: Assume same as today's releases but further research on the long-term effects of the chemicals released on ecosystems must be found--perhaps

longitudinal studies have been carried out
and the ecosystem surrounding an accident in the US was studied a decade after an accident

18. Magnitude of Future Consequences 3 6 9

NOTES:

REFERENCES

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: U.S.A.

ENVIRONMENTAL PROBLEM: 22. Stock of Fisheries

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES:

Score 1; only countries that make substantial use of large purse seine nets (i.e., Japan) will score higher.

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES:

Heavily used fisheries in the Northwest Atlantic (approx. 1/3 of US catch) and in the Northeast Pacific (1/3 of US catch) are being used at or above the levels of maximum sustainable yield (WRI89, pp328-9; SOTE, p.309; SOTW85, p.78). Examples (SOTW85, p.78):

NW Atl. Haddock losses 17% due to overfishing by US and Canada
NW Atl. Herring losses 25.3% " "
NE Pac. Halibut losses 61% " "
NE Pac. King Crab losses 82.5% due to US harvesting alone.

Other fisheries better managed, such as Mid-Atlantic (WRI89, p.328). Assume overfishing range R=1-10.

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES:

Several overused fisheries have shown significant recovery within a decade. Some extinction has occurred, however.

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES:

Ongoing activity.

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES:

Changes in territorial waters are affected by government quotas that are determined annually. Total U.S. catch has averaged 5-6% annual increase over the last decade (UNEP90, p.286)

7. Population at risk 1 3 5 7 9

NOTES:

Unclear. Everyone is at risk of diminished productivity. No significant subsistence fishing, however.

8. Land area at risk 1 3 5 7 9

NOTES:

Est. % of resource affected is defined as overfished/ depleted as % of US fishing grounds. 1/3 each Mexico Gulf and Pac. Coast; 1/6 each NW Atl. and Mid W. Atl.; Pac. Coast and NW Atl experiencing problems - 50%. (SOTE, p.309; WRI89. p.328-9).

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

Immediate; diminished stock to reproduce.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

No subsistence fishermen mortality in US.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

As above.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

Some extinction, but primarily productivity losses.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

Potentially very high, with 50% of resource threatened. Losses for some species currently on orders of 17-25% in NW Atl. and 60-80% in NE Pac. Est. (.2 * 1/6) + (.7 * 1/3) = approx. 30% of catch is threatened. 30% of $3 billion
catch is $900 million (Statistical Abstract of the US 1988, p.665).

14. Transgenerational 3 6 9

NOTES:

Under business as usual scenario, effects of mismanagement are significant.

15. Transnational 3 6 9

NOTES:

Given constant movement of fish in and out of territorial waters, other nations have impact on fisheries.

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

Unclear. Primarily welfare losses for U.S., minimal health consequences.

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

Business as usual will lead to continued deterioration.

18. Magnitude of Future Consequences 3 6 9

NOTES:

As above.

SUMMARY NOTES:

Fisheries pose special problems because uncooperative fish ignore the assumption of this model: a country's natural resources stay within the country. The 200 mile Exclusive Economic Zone claimed by many nations (as a result of the law of the sea negotiations of the 1970's and '80's) is an attempt to handle an oceanic "problem of the commons" by extending property rights. The world's most productive fisheries tend to lie within 200 miles of the shore. Therefore, it may make the most sense to focus on regional fisheries when ranking this problem.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: 23. Stock of Wildlife

1. Intentionality. 3 6 9

NOTES:
Intention to harm animals through hunting.

2. Spatial Extent 1 3 5 7 9

NOTES:
Local impact.

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Data for determining maximum sustainable yield is extremely limited to few game species; most species' MSY has not been determined. (Ducks and geese generally declining in number, primarily due to habitat loss, while big game generally stable or increasing ((SOTE)).)

Therefore, use status as endangered species as proxy for harvesting above MSY. WRI86, using OECD85 data, reports 6.4% of species endangered. OECD89 reports 7.5%. Unclear how much of increase is result of formal listing changes and how much is actual increase in number of endangered species. However, given continuing threats to large number of species, assume any harvesting or removal is too high.

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Some species extinction, much endangerment.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Hunting is ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Data on hunting rates is limited; use increased rate in species endangerment as proxy for increase: 0.3%/yr more species (see 3 above).

7. Population at risk 1 3 5 7 9

NOTES:
Subsistence hunters might be at risk; primarily animals alone are at risk.

8. Land area at risk 1 3 5 7 9

NOTES:
Depending on data, 6.4-7.5% of species are endangered and at risk.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Subsistence hunters could experience mortality, but no data suggests that this occurs at present.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
See 10 above.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Extinction of species.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Limits to tourism, etc. Approx. 330 million visits to parks annually in early 1980's (UNEP87, p.276) Approx. $40.9 billion spent on "fishing, hunting and non-consumptive wildlife activities" in 1980 (WRI87, p.79); approx. $1 billion spent non-consumptive activity (SOTE). Suppose 1% of this were endangered: $10-400 million under threat? Ballpark score of 4.

14. Transgenerational 3 6 9

NOTES:
Species extinction.

15. Transnational 3 6 9

NOTES:
Habitat destruction and hunting rates in neighboring countries will affect wildlife populations.

16. Commitment to Future Human Health Consequences. 1 3 5 7 9

NOTES:
As species become extinct, genetic material is lost that could have yielded new medicines, etc.

17. Commitment to Future Ecosystem Consequences. 3 6 9

NOTES:
Species extinction.

18. Magnitude of Future Consequences. 3 6 9

NOTES:
Species extinction.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: 24. Forestry Reserves

1. Intentionality. 3 6 9

NOTES:
Harm to animals is picked up under #23 habitat loss.

2. Spatial Extent 1 3 5 7 9

NOTES:
Primarily local impact. Losses to fires are small -- 0.2% in 1982 (UNEP90, p. 504).

3. Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Generally, growth rates exceed removal and reserves are building up, although localized overcutting occurs (SOTE, p.219; SOTW88, p.87; OECD89, p.119) Some decline in forest area over the past two decades, although generally stable patterns of land use (UNEP90, p.242; Clawson, Marion)

4. Persistence. 1 2 3 4 5 6 7 8 9

NOTES:
Most forestry activity is well managed on cycles of several decades.

5. Recurrence. 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. Rate of Change in material flux. 1 2 3 4 5 6 7 8 9

NOTES:
Quantity of forested land is generally stable, although national level yields are increasing due to better management. Harvests are increasing at approx. 5.7 million cubic meters/year while growth is increasing steadily at 6 million/yr over the period 1970-85 (OECD89, p.119). Total harvest is 483m, total growth is 764m: growth is 1.2% and 0.7% respectively. However, overcutting is still a significant problem in several regions.

7. Population at risk 1 3 5 7 9

NOTES:
No health effects.

8. Land area at risk 1 3 5 7 9

NOTES:
No resources at risk on national level.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
None.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
None.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
No significant effect from well managed forests.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No losses.

14. Transgenerational 3 6 9

NOTES:
All remaining descriptors scored lowest because current management practices are producing few foreseeable problems.

15. Transnational 3 6 9

NOTES:

16. **Commitment to Future Human Health Consequences.** 1 3 5 7 9

NOTES:

17. **Commitment to Future Ecosystem Consequences.** 3 6 9

NOTES:

18. **Magnitude of Future Consequences.** 3 6 9

NOTES:

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: U.S.A.

ENVIRONMENTAL PROBLEM: 25. Groundwater

1. **Intentionality.** 3 6 9

NOTES:

2. **Spatial Extent** 1 3 5 7 9

NOTES:
Regional impacts occur from single "groundwater mining" operation.

3.

Concentration. 1 2 3 4 5 6 7 8 9

NOTES:
Mining occurs mainly in West and Great Plains. R Ariz. = 1.7; R CA =1.4; R TX = 21. Est weighted ave in 1-10 range. (National Water Summary, USGS Water Supply Paper 2250, 1983 p. 36ff; CRS Report 5/80 "State and National Water Use Trends to the Year 2000) 26 of 122 billion cubic meters pumped annually is overdraft; 122/96 = 1.3 (SOTW86, p.59).

4. **Persistence.** 1 2 3 4 5 6 7 8 9

NOTES:
300 years until TX aquifers return to normal level; 110/500 million acre feet withdrawn and .372 million recharge per year. (USGS)

5. **Recurrence.** 1 2 3 4 5 6 7 8 9

NOTES:
Ongoing.

6. **Rate of Change in material flux.** 1 2 3 4 5 6 7 8 9

NOTES:
No data on rate of change in water levels; use rate of change in withdrawals as estimate. In 35 years, +190% extraction; 2% annually, 36 yr. doubling time.

7. **Population at risk** 1 3 5 7 9

NOTES:
No current health effects.

8. Land area at risk 1 3 5 7 9

NOTES:
Approx. 50% of 48 states experiencing some overdraft (WRI86, Troubled Waters, p. 52); 1/4 of 21 million ha are being mined (SOTW89, p.50); on 20% of irrigated lands, pumping is greater than recharge rates (SOTW90, p.45).

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:
Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No current mortality.

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
No current morbidity.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:
Groundwater is not habitat, little ecosystem interaction with groundwater.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:
Rough estimate: 20% of US agriculture occurs over Ogallala aquifer, where 7% less land is being irrigated. Agriculture is $84 billion industry: 20% * 7% * $84 billion = $1.2 billion. Added costs of increased scarcity and drilling for agriculture and drinking water supplies in Southwest and Great Plains, plus costs of saltwater intrusion in Florida, etc., could mean actual costs are magnitude higher. Score 6: $420 million to $4.2 billion.

14. Transgenerational 3 6 9

NOTES:
At current rates, many regions will be in significant trouble by the year 2000.

15. **Transnational** 3 6 9

NOTES:

16. **Commitment to Future Human Health Consequences.** 1 3 5 7 9

NOTES:
Assume no health consequences; loss in potential agriculture to be made up elsewhere, etc.

17. **Commitment to Future Ecosystem Consequences.** 3 6 9

NOTES:

18. **Magnitude of Future Consequences.** 3 6 9

NOTES: As water table sinks, increasing costs and problems.

WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Flooding

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: The effects of a single flood can spread for hundreds of miles

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: Assume floodwaters not higher than 100 times

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: Cropland can be so damaged that it may never recover since so much topsoil is washed away Human structures (dams, safety walls, port facilities, etc) can take more than a decade to rebuild Floods can leave behind less fertile silt than the original soil as in parts of the Southeastern United States--the originally more fertile soil never returns and the land is less productive

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: 1976-1986--1,679 floods in the US 1679/11 years = 152 floods/year 152/12=12.7/month 12.7/4 = 3.175/wk

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: 1966-1975 1,528 floods
1976-1985 1,599 floods
Increase of 4.6% in 10 years--difficult to determine change from data so scored a "5"

7. Population at risk 1 3 5 7 9

NOTES: Approximately 35% of the US lives in an area that is likely to be affected by a flood

8. Land area at risk 1 3 5 7 9

NOTES: The resource at risk would be all US land--

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: The sedimentation left by floods in cropland and water supplies may contain chemicals whose ingestion by humans may cause certain cancers--doubt if 20% of the problem is cancer so scored the more immediate effects of a flood

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 1976-1986---average of 160 people each year

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: Rated an order higher on the scale than mortality since no data found

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES: Need a better definition of "significant" in the categorical definition

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: 1966-1976 total damage was 38.7 million dollars
$38.7 million/21 = $1.843 million/year avg

14. Transgenerational 3 6 9

NOTES: The loss of fertility of the cropland can affect several generations if it does not recover--as in parts of the SE U.S.

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: United States

ENVIRONMENTAL PROBLEM: Drought

1. Intentionality 3 6 9

NOTES:

2. Spatial Extent 1 3 5 7 9

NOTES: Average size of a drought prone area in U.S.--score "regional" on scale

3. Concentration 1 2 3 4 5 6 7 8 9

NOTES: A drought defined by UNEP in the U.S.--50% of the area receiving less than 60% of the normal rainfall

4. Persistence 1 2 3 4 5 6 7 8 9

NOTES: One year--UNEP

5. Recurrence 1 2 3 4 5 6 7 8 9

NOTES: UNEP-- 3 droughts in the U.S. in 1980-1988

6. Rate of Change in material flux 1 2 3 4 5 6 7 8 9

NOTES: The activities which lead to drought--deforestation--also leads to global warming. Assume that the increase in the likelihood of global warming will cause an increase in droughts.

7. Population at risk 1 3 5 7 9

NOTES: No one in the U.S. is effected (health effects) by a food shortage due to a drought

8. Land area at risk 1 3 5 7 9

NOTES: Amount of semi-arid/arid land in U.S.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES: the time from a bad harvest to when the consumer might feel the effect of the drought

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES: No one dies in U.S. due to lack of food because of a drought

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES: See #10

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES: The three droughts in the 1980's reduced grain output in the U.S. by 1/3 (State of the World). The value of foodgrains from U.S. agriculture was 67 billion in 1985-1986. The reduction in the 1980's = 1/3*67 billion = $22 billion. The average was 7.3 billion each year of the drought

14. Transgenerational 3 6 9

NOTES:

15. Transnational 3 6 9

NOTES:

16. Commitment to Future Human Health Consequences 1 3 5 7 9

NOTES:

17. Commitment to Future Ecosystem Consequences 3 6 9

NOTES:

18. Magnitude of Future Consequences 3 6 9

NOTES:

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WORKSHEET FOR APPLYING CAUSAL TAXONOMY OF ENVIRONMENTAL PROBLEMS

COUNTRY: USA

ENVIRONMENTAL PROBLEM: 28. Pest Epidemics

1. **Intentionality.** 3 6 9

NOTES:
Pesticides are intended to kill pests.

2. **Spatial Extent** 1 3 5 7 9

NOTES:
Changed material flux is emergence of newly resistant species; unclear how to treat "release" of increased resistance. Extent is local initially, but spreads through reproduction.

3. **Concentration.** 1 2 3 4 5 6 7 8 9

NOTES:
Between 1980-84, 4.4% increases in resistant pest species worldwide, for annual increase of 1.09%. Individual species may be resistant to several pesticides, with [(new species) * (pesticides to which it is resistant)] = 9.4% over same period, 2.3% annual average (Pesticide Resistance, p.18).

4. **Persistence.** 1 2 3 4 5 6 7 8 9

NOTES:
Assume species resistance is essentially permanent.

5. **Recurrence.** 1 2 3 4 5 6 7 8 9

NOTES:
Approx. 4.75 new resistant species worldwide per year, ave one every 2.5 months. Assume newly resistant pests spread globally.

6. **Rate of Change in material flux.** 1 2 3 4 5 6 7 8 9

NOTES:
At 1.1% new species annually, doubling time is over 40 years. At 2.3% (new species * pesticides resistant) rate, doubling time is closer to 30 years. Use latter to focus on increased resistance, rather than increased species. (PestRes, p.18)

7. Population at risk 1 3 5 7 9

NOTES:

In US case, population at risk would be number exposed to vector born disease such as malaria. Approx. 1500 malaria cases annually in US (WRI87, p.254), although some of these may not be indigenous (WRI87, p.257). Pest epidemics such as grasshopper infestation possible, but population not substantially at risk.

8. Land area at risk 1 3 5 7 9

NOTES:

Agricultural lands are primarily exposed to changes in the VEC. US is 21% cropland and pasture, 29% woodland (UNEP90, p.243); some % of both is sprayed with pesticides. Assume score 7: 30-70% of land.

9. Delay 1 2 3 4 5 6 7 8 9

NOTES:

Immediate.

10. Human mortality (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

Vector born disease mortality is low in US; 3 malaria cases, 36 other arthropod borne cases in 1983 (World Health Statistics 1986, WHO, p.256).

11. Human morbidity (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

See 7 and 10 above. Approx. 1500 malaria cases annually.

12. Natural ecosystem impacts (current annual) 3 6 9

NOTES:

Significant declines in agricultural productivity due to increased resistance and epidemics.

13. Welfare effects (current annual) 1 2 3 4 5 6 7 8 9

NOTES:

$2.8 billion spent annually on pest control, $133 million due to increased pest resistance and $153 million due to loss of natural enemies = $286 million in 1979 (PestRes, p.33). Additional costs of $20 million per new pesticide developed to handle increased resistance. Crop losses to pest epidemics unclear, but assume score 6: $420 million-$4.2 billion.